THE ECONOMIC AND FINANCIAL IMPLICATIONS OF SUPPLYING A BIOENERGY CONVERSION FACILITY WITH CELLULOSIC BIOMASS FEEDSTOCKS

A Thesis

by

WILL ALLEN McLAUGHLIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for a degree of

MASTER OF SCIENCE

December 2011

Major Subject: Agricultural Economics

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ABSTRACT

The Economic and Financial Implications of Supplying a Bioenergy Conversion Facility with Cellulosic Biomass Feedstocks. (December 2011)

William Allen McLaughlin, B.S., Texas A&M University

Co-Chairs Advisory Committee: Dr. M. Edward Rister
Dr. Ronald D. Lacewell

Comprehensive analyses are conducted of the holistic farm production-harvesting-transporting-pre-refinery storage supply chain paradigm which represents the totality of important issues affecting the conversion facility front-gate costs of delivered biomass feedstocks. Targeting the Middle Gulf Coast, Edna-Ganado, Texas area, mathematical programming in the form of a cost-minimization linear programming model (Sorghasaurus©) is used to assess the financial and economic logistics costs for supplying a hypothetical 30-million gallon conversion facility with high-energy sorghum (HES) and switchgrass (SG) cellulosic biomass feedstock for a 12-month period on a sustainable basis. A corporate biomass feedstock farming entity business organization structure is assumed. Because SG acreage was constrained in the analysis, both HES and SG are in the optimal baseline solution, with the logistics supply chain costs (to the frontgate of the conversion facility) totaling \$53.60 million on 36,845 acres of HES and 37,225 acres of SG (total farm acreage is 187,760 acres, including HES rotation acres), i.e., \$723.67 per harvested acre, \$1.7867 per gallon of biofuel produced not including any conversion costs, and \$134.01 per dry ton of the requisite 400,000 tons of biomass feedstock.

Several sensitivity scenario analyses were conducted, revealing a potential range in these estimates of $84.75-$261.52 per dry ton of biomass feedstock and $1.1300-$3.4870 per gallon of biofuel. These results are predicated on simultaneous consideration of capital and operating costs, trafficable days, timing of operations, machinery and labor constraints, and seasonal harvested biomass feedstock yield relationships. The enhanced accuracy of a comprehensive, detailed analysis as opposed to simplistic approach of extrapolating from crop enterprise budgets are demonstrated. It appears, with the current state of technology, it is uneconomical to produce cellulosic biomass feedstocks in the Middle Gulf Coast, Edna-Ganado, Texas area. That is, the costs estimated in this research for delivering biomass feedstocks to the frontgate of a cellulosic facility are much higher than the $35 per ton the Department of Energy suggests is needed. The several sensitivity scenarios evaluated in this thesis research provides insights in regards to needed degrees of advancements required to enhance the potential economic competitiveness of biomass feedstock logistics in this area.

ACKNOWLEDGMENTS

I would first like to thank my committee co-chairs, Dr. Ed Rister and Dr. Ron Lacewell, for their guidance, support, and encouragement during the research and writing of this thesis. I am especially grateful and indebted to Dr. Rister related to development of the model and involvement in drafting the thesis. I would also like to thank the other members of my committee, Dr. Juerg Blumenthal and Dr. Bill Rooney for their willingness to estimate parameters for the yields and production of Switch Grass and High Energy Sorghum under the many scenarios; Dr. Larry Falconer for the help with crop enterprise budgets and potential for alternative feedstock; Dr. B.L. Harris provided insight on agronomic issues and potential alternatives; and Dr. Dean McCorkle for guidance and assistance in developing economic and employment impacts. The leadership and knowledge of these committee members made much of this research possible. Ann Conrad's collaboration during our graduate research investigations of biomass feedstocks was rewarding and is deserving of recognition. In addition, I would like to thank Allen Sturdivant, whose WordPerfect knowledge and morale support enabled me to complete this thesis. Thanks also to Melissa Kindell for her countless hours editing, reading, and re-editing this thesis. Kari Moore's managing my graduate paperwork and other trials and tribulations and Ms. Michele Zinn's editing of the final version of my thesis are gratefully acknowledged. The assistance of Mark Wylie of LINDO Systems, Inc. and Bart Basile, computer technician in the Department of Agricultural Economics, Texas A&M University, in facilitating the installation and successful implementation of the software packages used in my research is also much appreciated. A special thanks to Dr. Shelley Peacock and Ms. Vicki Heard for overseeing the onerous details of my graduate program and helping to keep me on track toward graduation.

The willingness to give of their time and expert insights relative to the study region by L.G. Raun, Michael Popp, Dick Ottis, and Mr. Mickelson is deeply appreciated and contributed to bringing realism to the results. In addition, the partial financial support of the Bio Energy Program at Texas AgriLife Research through Bob Avant for this effort is gratefully acknowledged.

I would also like to thank my wife, Ashley McLaughlin and my love puppy, Hali Bells, for their patience, love, and continued support. Finally, I would like my parents, Neal and Dierdre McLaughlin, for their love and support in everything I do.

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VITA. 654

INTRODUCTION

The production of fuels from renewable sources is an issue of growing importance as the United States (U.S.) investigates ways to improve energy security and gain independence from foreign oil. The U.S. is heavily dependent on oil, which supplies more than 40 percent of the nation's total energy demand and more than 99 percent of the fuel that is used in the transportation sector (U.S. Department of Energy 2009a). The real price of crude oil in 2009 dollars has exhibited an upward trend over the past ten years, ranging from \$13.71 per barrel in January 1999 to \$127.73 per barrel in July 2008 (U.S. Energy Information Administration 2009). The historical trends in nominal and real imported crude oil prices are illustrated in figure B1.

The U.S. is the world's leading consumer of petroleum, using a total of 19.5 million barrels each day, or 25 percent of total world petroleum consumption, but it (i.e., the U.S.) only produces 6.7 million barrels per day (U.S. Energy Information Administration 2008). Since the U.S. is incapable of producing sufficient petroleum to meet its energy short falls, imports are important. The U.S. imports 12.92 million barrels of petroleum per day, or 60 percent of its total domestic use, leaving the U.S. vulnerable to price spike and supply disruptions by countries exporting to the U.S. (U.S. Energy Information Administration 2008; Bureau of Transportation Statistics 2010). This dependence on foreign oil and the high domestic demand have prompted both the

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This thesis follows the style of *American Journal of Agricultural Economics.*

federal government and private sector to explore alternative sources of energy that are sustainable and can be produced domestically.

Fuels produced from cellulosic biomass have been identified by the United States Department of Energy as a means to enhance the security of the U.S. energy supply and reduce the U.S. dependancy on imported petroleum. Cellulosic biofuels such as ethanol, pyrolysis liquids, gasoline, and jet fuel can be produced from biomass resources using dedicated energy crops, forest resources, logging and mill residues, agricultural crop residues, and municipal waste (National Renewable Energy Laboratory 2007; U.S. Department of Energy 2009a). These fuels are projected to offer distinct advantages over starch-based ethanol and fossil fuels in that they have the potential to reduce net CO_2 emissions to almost zero, they can be produced from a very diverse resource base, and their production generates economic benefits for rural communities through the creation of new jobs and new industries (Solomon, Barnes, and Halvorsen 2007; Knauf and Moniruzzaman 2004).

The Biomass Research and Development Technical Advisory Committee established a goal that biomass-based energy will supply five percent of the nation's power, 20 percent of its transportation fuels, and 25 percent of its chemicals by 2030, approximating 30 percent of the nation's current petroleum consumption (U.S. Department of Energy 2003). A later estimate by the U.S. Department of Energy (2005) suggests that by using cellulosic biomass, a resource base of 1.3 billion dry tons of biomass feedstocks can be attained with the potential to produce enough biofuels to meet one-third of the current demand for fuels in the transportation sector. The immature nature of the cellulosic biofuels industry represents significant challenges, however, in that the industry lacks the infrastructure for the acquisition and logistics of cellulosic biomass. The logistics costs associated with cellulosic biomass are one of the largest obstacles to the successful growth and development of the cellulosic biofuels industry and will impact the rate at which the industry grows (Hess,Wright, and Kenney 2007).

Biomass feedstock production and logistics costs comprise 35 to 65 percent of the total production cost of cellulosic biofuels and largely impact the financial and economic competitiveness of these fuels (Fales, Hess, and Wilhelm 2007). Biomass feedstock logistics encompass all of the operations required to grow, harvest, transport, and store the biomass feedstock and guarantee that a delivered biomass feedstock meets the specifications of a conversion facility (Energy Efficiency and Renewable Energy 2008).

From a perceived biomass-based ethanol production cost of $2.25 per gallon in 2005, the United States Department of Energy's National Renewable Energy Laboratory has set a cost target goal to reduce the logistics cost to $0.39 per gallon in 2012. This objective is intended to assist in making cellulosic ethanol cost competitive at a production cost of $1.07 per gallon. The 2012 goal is approximately equal to a biomass feedstock cost of $35 per dry ton assuming an average conversion rate of 90 gallons of fuel per dry ton (U.S. Department of Energy, Office of Biomass Program 2009; Epplin et al. 2007; Pacheco 2006).

Biomass feedstock costs are dependant on a variety of factors such as biomass feedstock variety, yield, location of the conversion facility relative to the field, and the harvest, collection, storage, and transportation systems used (Hess, Wright, and Kenney 2007). To minimize these costs, the variety of biomass selected must be both environmentally and economically sustainable within the conversion facility's operating region and the crop density (i.e., acres planted per square mile) and energy yield per acre (i.e., gallons of biofuels that can be produced) of the selected biomass feedstock must be adequate so that transportation and other logistics cost can be controlled (Fumasi, Richardson, and Outlaw 2008).

This thesis examines the total and per dry[1] ton cost to supply a hypothetical 30-million gallon conversion facility with high-energy sorghum (HES) and switchgrass (SG) for a 12-month period on a sustainable basis. HES and SG were selected for analysis due to their ability to produce large amounts of dry weight biomass per acre, their relatively low input usage, and the fact that the climate found in the southeastern U.S. is well suited for the production of these crops (Fumasi, Richardson, and Outlaw 2008; Mitchell, Vogel, and Sarath 2008). Alternatives in production practices and other factors are considered in sensitivity analyses to gain insight on their cost impacts to deliver a reliable supply of biomass feedstock to the conversion facility, assuming these biorefineries must operate 365 days a year to be cost competitive (Avant 2009; Rooney 2010). A bi-weekly linear programming model was developed and applied to determine the supply-chain

[1] A "dry" ton is assumed to be at 15 percent moisture (Blumenthal 2010; Rooney 2010).

costs and the capital, labor, and variable inputs required for the proposed biomass production system.[2]

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[2] Microsoft® and Excel® are registered trademarks of the Microsoft® Corporation. LINDO® is a registered trademark of LINDO SYSTEMS, INC. GAMS is a mathematical programming model copyrighted by The International Bank for Reconstruction and Development/The World Bank (Brooke, Kendrick, and Meeraus 1988).

All product names known to be trademarks have been identified and capitalized appropriately. Mention of a trade name does not constitute a recommendation by Texas AgriLife Research or Texas AgriLife Extension Service or Texas A&M University.

OBJECTIVES

This research addresses the financial and economic costs of supplying a hypothetical 30-million gallon cellulosic biomass conversion facility with alternative biomass feedstocks for one year, on a sustainable basis. A review of literature indicates biomass feedstock costs can account for a significant amount of the total production costs of cellulosic biofuels and must be reduced for these biofuels to become economically competitive and significantly contribute to U.S. transportation fuel supplies. This analysis evaluates the financial and economic logistics costs by focusing on a set of specific objectives, which include: (1) establishing production alternatives to produce HES and SG, (2) establishing harvesting, transporting, and storage options for biomass crops as well as options to purchase alternative biomass feedstocks,[3] and (3) incorporating all alternatives into a cost-minimizing analytical model. Applications of the model include sensitivity analyses to provide direction to related agronomic and engineering research that can make the greatest impact in reducing costs and to determine those factors contributing most to the cost of cellulosic biofuels. It is noteworthy that all analyses conducted are void of any consideration of subsidies.

As noted by Rooney (2011), the approach taken in this thesis research is the reverse of the normal approach by others, i.e., they are using perennial (e.g., SG) as base

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[3] Features for considering the purchase of alternative biomass feedstocks to supplement the production of HES and SG are incorporated into the cost-minimization (Sorghasaurus©) model developed in this thesis research. However, these features are not utilized due to a plethora of other sensitivity analysis coordinates as associated with the HES and SG logistics supply chain.

source and annual (e.g., HES) as insurance. This thesis research is focused on evaluating the economic and financial potential for producing HES biomass feedstocks in the targeted study area, with SG used for supplemental purposes. A sensitivity analysis relying solely on SG as the source of biomass feedstock for a biofuel conversion facility is used to isolate and evaluate the point made by Rooney (2011).

In accordance with the scientific method, two null (Ha_0 and Hb_0) and two alternative (Ha_1 and Hb_1) hypotheses are developed and considered in this study. These pairs of hypotheses (i.e., a and b) are evaluated and a conclusion is reached with respect to each hypothesis to either (I) fail to reject the null hypothesis or (II) reject the null hypothesis and accept the alternative hypothesis. The null and the corresponding alternative hypotheses evaluated are:

Ha_0: Dedicated cellulosic biomass feedstocks <u>can</u> be produced and delivered to a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area at an economically and financially feasible cost that is competitive with other alternative sources;

Ha_1: Dedicated cellulosic biomass feedstocks <u>cannot</u> be produced and delivered to a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area at an economically and financially feasible cost that is competitive with other sources;

and

Hb_0: A diverse portfolio of biomass feedstocks is required to secure a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with a continuous, year-round supply of biomass feedstock; and

Hb_1: A diverse portfolio of biomass feedstocks is not required to secure a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with a continuous, year-round supply of biomass feedstock.

The results are intended to provide policy makers, the U.S. Department of Energy, local community crop producers, Texas AgriLife Research and Texas AgriLife Extension Service faculty and administration, and industry professionals with a robust analysis of the factors impacting supplying cellulosic biomass feedstock to a conversion facility. Included in the information set are details regarding the costs to supply a conversion facility with alternative biomass feedstocks and identification of areas where further advances in technology are needed to spur the growth and development of the cellulosic biofuels industry.

The remainder of this thesis is organized to first develop a background of cellulosic biomass feedstocks and issues associated with their production, and second to introduce the model and data used. Subsequently, baseline and sensitivity analyses results are presented and discussed. The major sections included and a brief description of each are described below:

- Literature Review. Develop background information on the cellulosic biofuels industry and U.S. government energy policies that impact this industry.
- Research Paradigm. Present and outline the proposed operational structure of the biomass feedstock production unit(s) and method to capture economies of scale.
- Theoretical Basis. Describe the economic and financial principles that are the basis of this research.
- Model (Sorghasaurus©). Develop an analytical cost-minimization optimization model and apply it to estimate economic and financial implications of biomass production, harvest, transportation, and storage logistics.
- Description of Sorghasaurus©. Explain the structure of the model and how the several distinct factors incorporated in Sorghasaurus'© robust structure function in the aggregate, interlinked form of the model.
- Base Results. Describe results generated for a baseline situation.
- Sensitivity Analyses. Identify alternative sensitivity scenarios and their implications relative to the base analysis.
- Economic Impact Analysis. Present an analysis of the economic and financial impacts of this proposed operation on the Middle Gulf Coast, Edna-Ganado area, state, and national economies in terms of economic activity and employment.

- Challenges, Limitations, and Future Research Needs. Identify and discuss the boundaries and related omissions contributing to noted limitations of the model and reported analyses that need to be recognized while interpreting the results and in designing and implementing future research.
- Conclusions. Present the conclusions drawn from the base and sensitivity analyses as well as that of the economic impact analysis within the paradigm of the thesis' research.
- Tables, Figures, and Exhibits. Within Appendixes A, B, and C, respectively, present the tables, figures, and exhibits corresponding to the primary text.
- Description of Data. Within Appendix D, present details regarding, the data and calculations used for the base analysis.
- Discussion of Sensitivity Scenarios. Within Appendix E, elaborate on details of the several sensitivity scenarios investigated.

REVIEW OF LITERATURE

A review of selected literature is provided in this section to address the various facets of this thesis research. The literature review includes (1) federal policies, (2) the economic and financial feasibility of using biomass as an alternative energy source, (3) the basic characteristics of HES and SG biomass feedstocks and their production, and (4) biomass conversion technologies.

United States Federal Policies and Funding

Recent federal policy has the goal of decreasing the U.S. demand on foreign fuels as well as providing a clean-burning fuel to reduce greenhouse emissions. The major focus of these policies is on increasing the domestic production of advanced biofuels through research grants, private loan initiatives, biofuels marketing, demonstration projects, and producer incentives. Substantial portions of government-based funding and federal policies are focused on the science of converting plant material into fuels, with little interest directed toward the logistics of biomass production (Avant 2009).

The Energy Independence and Security Act of 2007 mandates that 36 billion gallons of renewable fuels be produced annually by 2022, with 16 billion gallons of the total being cellulosic biofuels[4]. The Act also provides $25 million in annual funding to provide grants for biofuels research, development, demonstration and commercial

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[4] Using 2008 U.S. petroleum production to forecast U.S. petroleum production for the 16 year period, 36 billion gallons of renewable fuels represent 92 percent of total petroleum production so 16 billion gallons of cellulosic biofuels represent 41 percent (U.S. Energy Information Administration 2008).

applications for states where the level of ethanol production is low. A program also exists to provide up to $2 million in grants to universities for research and development of renewable energy technologies. The purpose of this Act is "to move the U.S. toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes" (H.R. 6--110th Congress 2007).

Title IX of the 2008 Farm Bill focuses on the development and sustainability of renewable energy sources, primarily energy derived from biomass or bio-based sources. The 2008 Farm Bill authorizes $1 billion in overall funding to support energy-related programs and to promote investments in new technologies and alternative biomass feedstocks. Included in this authorization is $320 million in loan guarantees to biorefineries to support the development of new and emerging technologies, as well as $35 million to encourage existing biorefineries to reduce the amount of fossil fuels used to operate their facility[5]. The 2008 Farm Bill also mandates $300 million in funding for the Bioenergy Program for Advance Biofuels aimed at providing incentive-based payments to producers to ensure an expanding production of biomass crops. The amount of the payments to eligible producers are based on: (1) the quantity and duration of production by the producer, (2) the net nonrenewable energy content of the biofuel, and (3) other factors deemed appropriate by the Secretary of Agriculture. The program limits

[5] The energy balance issue (Pimental and Pimental 1996) is a critical focal point in this research.

the amount of funds provided to conversion facilities with a total refining capacity of more than 150 million gallons per year to be no more than five percent of the funds available each year. It establishes a Biomass Crop Assistance Program (BCAP) to provide financial assistance to producers of biomass crops for the establishment, collection, harvest, storage, and transportation of biomass feedstocks to a biomass conversion facility. Payments made under this program for the establishment of perennial crops will compensate producers up to 75 percent of the establishment costs for perennial biomass crops grown on BCAP contract acreage[6]. During the first two years of operation, payments to producers for the collection, harvest, storage, and transportation of biomass feedstocks may be subsidized by the government at a matching rate of $1 for each $1 per ton paid by the biomass conversion facility, not to exceed an amount more than $45 per ton (H.R. 2419--110th Congress 2008). The 2008 Farm Bill provides many provisions designed to foster further development and implementation of cellulosic biomass feedstocks into the U.S. energy sector.

The U.S. Department of Energy (DOE) has provided $375 million ($125 million for each center over five years) in funding for three bioenergy research centers intended to enhance conversion technologies and accelerate basic research in the development of cellulosic ethanol and other biofuels. The major focus of the centers is on determining how to reengineer biological processes to develop new, more efficient techniques for converting cellulosic plant material into ethanol or other biofuels. The three centers are:

[6] Establishment cost are interpreted from the 2008 Farm Bill to include: (1) the cost of seeds and stock for perennials, (2) the cost of planting the perennial crop, and (3) if nonindustrial private forest land is used, the costs of site preparation and tree planting (H.R. 2419--110th Congress 2008).

(1) the DOE BioEnergy Science Center at Oak Ridge, Tennessee; (2) the DOE Great Lakes BioEnergy Research Center at Madison, Wisconsin; and (3) the DOE Joint BioEnergy Institute at Emeryville, California.

The DOE BioEnergy Science Center is led by Oak Ridge National Laboratory and is studying the potential energy crops of poplar and SG. The main focus of this center is on the resistance of plant fiber to breakdown into sugars. The DOE Great Lakes BioEnergy Research Center is led by the University of Wisconsin in collaboration with Michigan State University and is investigating methods to increase plants' production of starches and oils. The scientists at this center are also studying the environmental and socioeconomic implications of moving towards a biofuels-based economy. The DOE Joint BioEnergy Institute is led by the Lawrence Berkeley National Laboratory and is focused on finding game-changing breakthroughs in basic science by studying the "model" crops of rice and Arabidopsis[7]. The scientist at the center are also studying microbial-based synthesis of fuels beyond ethanol (U.S. Department of Energy 2009b).

The focal point of a large portion of the research and government-based funding is on the science of converting plant material into fuels, with there being little apparent interest in the logistics and cost of energy crop production. Several studies indicate logistics costs are an important factor, however, and that they must be reduced for cellulosic biofuels to be competitive with petroleum. Hess, Wright, and Kenney (2007)

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[7] *Arabidopsis thaliana* "is a small, flowering plant that is widely used as a model organism in plant biology. Arabidopsis is a member of the mustard (*Brassicaceae*) family, which includes cultivated species such as cabbage and radish. Arabidopsis is not of major agronomic significance, but it offers important advantages for basic research in genetics and molecular biology" (National Institute of Health 2010).

estimate a conversion facility using biochemical conversion processes will be able to allocate 35 percent of the minimum ethanol selling price to the purchase and supply of biomass feedstock. Fales, Hess, and Wilhelm (2007) estimate that biomass feedstock logistics costs must be reduced to less than 25 percent of the total production cost for cellulosic ethanol to be a reliable and competitive source of fuel. Thus, establishing the expected cost of supplying a cellulosic conversion facility with biomass feedstocks is the first step in identifying critical costs to be reduced. It is anticipated the reduction of biomass feedstock logistics costs to make cellulosic biofuels economically and financially competitive with petroleum will be a formidable industry goal.

Economics of Energy Crop Production

Few studies, if any, have been conducted that include a detailed analysis of all the components, time constraints, labor, and investment and operating costs required to supply cellulosic biomass to a conversion facility on a commercial scale. Research has been performed on many of the segments involved in the supply chain system, such as transportation logistics and production economics, but few, if any, have combined these processes into a holistic analysis.

Much of the economic literature focuses on minimizing the costs associated with energy crop production because this is seen by many as a major hurdle towards the integration of energy crops into the supply system. McCutchen, Avant, and Baltensperger (2008) provide an overview of the prospects for using sorghum-breeding developments and energy cane as dedicated lignocellulosic biomass crops. They address characteristics of these two principal cropping mechanisms and the related land-management challenges, including required changes in rotational cropping systems. Included in their assessment is an unsourced comparison of dry tonnage biomass annual yields and estimated costs for delivering the same to conversion facilities. Included in these cost estimates are SG at 8 tons per acre at a cost of $60-90+ per ton and bioenergy sorghum at 15-20 tons per acre at a cost of $50-60 per ton. Their comments conclude with noting "a thorough evaluation must be conducted to assure producer buy-in." (McCutchen, Avant, and Baltensperger 2008, p. 121).

A study conducted by Fumasi, Richardson, and Outlaw (2008) for the Beaumont, Texas area focused on the interaction between various factors such as yield risk, technological expertise, and capital investment on the contract price needed to induce farmers to grow cellulosic biomass feedstocks compared to other enterprises. In addition, the project considered how bio-density, fuel prices, and type of crop produced impact the transportation and harvesting costs. The four energy crops evaluated were hybrid sorghum hay, hybrid sorghum green chop, high-biomass sorghum green chop, and billeted hybrid sugarcane. The most viable non-energy-based enterprises for the Beaumont, Texas area were determined to be cattle, rice, and pasture hay. Monte Carlo simulation was used to forecast the net returns to producers for growing both energy and non-energy crops for a five-year period. It was assumed harvest and transportation of the energy crops are performed by the biorefinery. The results from this study showed billeted hybrid sugarcane to be the most-favorable energy crop from a producer perspective because of the low yield risk, minimal input cost sensitivity, and potential income relative to current enterprises. Harvesting and transportation costs accounted for the majority of the total-delivered costs to the conversion facility (i.e., 50 to 75 percent). High-biomass sorghum was found to be the most-economically favorable crop for the conversion facility due to its low $32 per ton dry matter cost delivered to the conversion facility. This study concluded that harvesting and transportation costs accounted for 50 percent or more of the delivered biomass feedstock costs, regardless of the type of crop produced.

Turhollow (1994) estimated costs for 1989 and projected costs for 2010 production circumstances to grow and supply a biorefinery with biomass for four different cropping strategies in the Midwest and Southern regions of the U.S.[8]. The costs of producing hybrid poplar, sorghum, SG, and energy cane crop mixes were estimated by examining factors such as production systems, variety, pre-treatment, regions, and site variability. Crop enterprise budgets were established for these biomass crops as well as for traditional agricultural crops to determine a breakeven price per ton and to identify those biomass-cropping strategies that would be competitive with traditional crops. Turhollow's (1994) results indicate energy crops must sell between $48 and $66 per dry ton in 1989 and between $33 and $48 per dry ton in 2010 to be competitive with corn from the Midwest and soybeans from the Southeast[9]. Harvesting, handling, storing, and

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[8] The study was performed in 1989 and current cost estimates were obtained for that year. Cost estimates for 2010 were projected based on changing production circumstances and technology (Turhollow 1994).

[9] The selling price for dedicated energy crops is reduced in 2010 based on the assumption that dedicated energy crops will have a higher biomass yield and machinery costs will be lower than in 1989 (Turhollow 1994).

transportation of the biomass feedstock comprised approximately 40 percent of the total costs of production. The study also found that by applying "Just-In-Time" delivery and avoiding storage, costs could be reduced by $7 to $21 per dry ton (representing 21 to 44 percent of total costs).

An analysis conducted by the U.S. Environmental Protection Agency (2009), using data from Purdue University, School of Industrial Engineering and the U.S. Forest Service, estimates the logistics costs to supply a 100-million gallon per year conversion facility with agricultural residues, energy crops such as SG and miscanthus, forestry residue, and municipal solid waste.[10, 11] Corn stover is used as the agricultural residue biomass feedstock of choice because it is likely to make up a large portion of the future cellulosic biomass feedstock supply according to the U.S. Environmental Protection Agency (2009). The stover is shredded, raked, "square"-baled, gathered, and stacked at the side of the field, and then transported to satellite-storage areas where it remains until it is hauled to the conversion facility on an as-needed basis. This study also takes into account the costs to replenish the soil with the nutrients removed from harvesting all residues. The total logistics costs for corn stover are estimated to be $88.15, $88.64, and $89.38 per ton for farm sizes of 200, 400, and 800 acres, respectively, essentially representing no economies of size.

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[10] In this study, "forest residue" includes logging residues, other removals (i.e., clearing trees for new building construction), timberland trimmings (e.g., forest fire prevention strategy), and mill residues (U.S. Environmental Protection Agency 2009).
[11] "Municipal solid waste" includes biomaterials such as grease and animal fats, tin, iron, aluminum, other metals, painted woods, construction residue, plastics, and glass (U.S. Environmental Agency 2009).

These cost are divided into "farm gate" costs and "field to conversion facility" costs. The "farm gate" costs are estimated to be \$44.91, \$45.46, and \$46.20 per ton, respectively, for the three different farm sizes and the "field to plant" costs are estimated at \$43.18 per ton, the same for all three farm sizes. Transportation costs from the field through satellite storage to the conversion facility comprised 38.6 percent of the total logistics cost of delivered corn stover while the costs associated with harvesting (shred, rake, and bale) averaged 22.6 percent for the three different farm sizes.

Energy crops (e.g., SG) are expected to have a lower cost than agricultural residues due to their (i.e., energy crops) higher production density per acre, which allows for shorter transportation distances and fewer satellite storage areas. The costs for supplying SG to a 100-million gallon conversion facility were estimated to be \$77.15 per ton of biomass feedstock. Transportation costs for SG biomass feedstock are lower (than for agricultural residue biomass feedstock) at \$25.06 per ton and comprise 32.48 percent of the total-delivered costs. The "farm gate costs" are only slightly reduced to \$44.20 per ton in comparison to agricultural residues at \$44.91, \$45.46, and \$46.20 per ton, but there is a significant reduction in the "field to conversion facility" transport costs, which are \$32.95 per ton in comparison to \$43.18 per ton for agricultural residues (U.S. Environmental Protection Agency 2009).

The methods for collecting and harvesting forest residue and municipal solid waste vary significantly from that of agricultural residues and energy crops (U.S. Environmental Protection Agency 2009). Forest residues and municipal solid waste require further processing such as chipping branches and stumps or removing tin, iron, and other non-biological waste materials. These processes can potentially increase the costs of forest residues and municipal solid waste to levels not economical for energy production. The supply amount and approximated acquisition prices (not including processing and transportation cost) of forest residues available in each state for biofuels production were estimated by the U.S. Forest Service and are summarized for Texas and Louisiana in table A1.

The prices in table A1 are representative only of the costs of the raw source forest residue. A purchase price of $45 per dry ton for raw source forest residues was recommended by the U.S. Forest Service as the base pricing point for the U.S. Environmental Protection Agency (2009) study. However, it was assumed the wood residues would need to be further ground or chipped in the field to allow for more efficient transportation systems. This processing cost adds an additional $11 per dry ton to the biomass feedstock purchase price. Furthermore, transportation of the wood biomass can account for about 25 to 50 percent of the total-delivered cost depending on haul distance, residue moisture content, fuel prices, and semi trailer capacity. Transportation costs of $14 per dry ton were assessed in this study, using a Class 8 over-the-road truck. The total-delivered cost for woody biomass (including purchase price, grinding, and transportation) was estimated to be $70 per dry ton (U.S. Environmental Protection Agency 2009). Assuming equal conversion efficiencies, a price of $70 per dry ton appears as the pricing point HES must match to be a competitive source of biomass feedstock.

Municipal solid waste is available in large quantities in most areas, but requires extensive sorting due to the diverse nature of the biomass feedstock. Texas classifies municipal solid waste (MSW) by the source rather than the constituents or properties of the materials[12]. Municipal solid waste is a combination of residential and commercial residues, construction and demolition debris, Class 2 non-hazardous industrial solid waste such as solidified industrial sludges contaminated with metals and organics, Class 3 industrial solid waste not readily decomposable (i.e., bricks), sludge, brush, soil, and all other waste materials. In 2006, 20.45 million tons of MSW were generated in Texas, with an estimated energy content of 365 million BTUs, assuming 6,000 BTU per pound. This magnitude of MSW equates to a landfill disposal rate of 7.1 pounds per person, excluding construction and demolition debris and treatment plant sludge (Comptroller's State Energy Conservation Office 2008). The percentage contribution of each source of MSW to the total waste stream in Texas is presented in table A2.

The costs to sort MSW estimated by the U.S. Environmental Protection Agency (2009) study are between $30 and $40 per ton, but can be partially offset because landfill tipping fees are avoided[13]. Landfill tipping fees were estimated from the national average rate to be around $30 per ton. MSW is more costly and difficult to transport than other cellulosic biomass feedstocks because it is mainly collected in urban, densely-populated

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[12] The Texas Commission on Environmental Quality defines Municipal solid waste (MSW) as "waste resulting from or incidental to municipal, community, commercial, institutional, and recreational activities. MSW includes garbage, rubbish, ashes, street cleanings, dead animals, abandoned automobiles, and all other solid waste other than industrial waste" (Texas Commission on Environmental Quality 2009).

[13] "Landfill tipping fees" are the charges imposed by a landfill for receiving a given quantity of waste (Texas Commission on Environmental Quality 2007).

areas. This factor makes transportation more difficult and costly. The U.S. Environmental Protection Agency study (2009) estimates the cost to transport MSW from the point of origin to the conversion facility is $15 per ton and estimates the cost to grind and prepare the MSW as a biomass feedstock is $11 per ton. Thus, the net total-delivered cost of MSW was estimated to be between $26 and $36 per ton, mainly because landfill tipping fees are avoided (U.S. Environmental Protection Agency 2009).[14]

As noted in Conrad,

> A study by Larson et al. (2010) examined the various costs of logistics methods of SG production, harvesting, storage, and transportation in Tennessee using capital budgeting. The methods were traditional large round and rectangular bale harvest and storage systems and preprocessing facilities using field-chopped material. The study also estimated changes from adjustments in operating costs, dry matter loss during storage, investment requirements, and possible savings in transportation costs between the methods.
>
> If delivered to the biorefinery immediately after harvest, the total cost of producing SG in a round bale was estimated to be $78.27, a rectangular bale $67.70, and a preprocessed bale $65.76. . . . The baler machinery for tractors was shown to be a significant investment cost.

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[14] The calculation for the net delivered cost of MSW is demonstrated here: $30 to sort - $30 landfill tipping fee + $15 transportation cost + $11 for grinding = $26 per ton; $40 to sort - $30 landfill tipping fee + $15 transportation cost + $11 for grinding = $36 per ton.

> These results suggest the preprocessing facility system would perform better than conventional hay methods in terms of delivered cost to the biorefinery, and traditional hay systems might not be the most cost-effective.

In a more recent investigation, Griffith, Epplin, and Kakani (2011) note the advantages of using mathematical programming as opposed to standard enterprise budgeting. Their preliminary results are indicative that biomass feedstock production costs are higher than popular estimates. Fewell, Bergtold, and Williams (2011) are evaluating producers' willingness to produce biomass feedstocks. Using an extensive producer survey as the basis of their conclusion, they note the apparent necessity of offering incentive payments as part of an extended (i.e., multiple year) contract to entice producers to abandon their current enterprises.

Exhibit C1 is an itemized listing of the several logistics costs estimates reported in this literature review. These values are summarized in the exhibit to provide a platform for subsequent comparison with the estimates derived in this thesis research.

High-Energy Sorghum Characteristics and Production

Sorghum is a highly-productive annual grass that is well adapted to grow in hot, dry regions of the world. These plants are naturally drought tolerant and are very efficient users of water, requiring one-third to one-half less water than corn (Butler and Bean 2009). The drought tolerance trait reduces the risk of crop loss and maintains yield potential throughout the growing season (Rooney 2010). Sorghum can be classified as sweet sorghum, grain sorghum, or forage sorghum, depending on its genetic composition and intended end use. Texas AgriLife Research plant breeders have developed a new HES that is designed for biomass and energy production (Blumenthal et al. 2007).

High-energy sorghums are photoperiod-sensitive hybrids that combine the characteristics of grain and sweet sorghums (Monk, Miller, and McBee 1984), creating a plant specifically designed for biomass production. Due to their photoperiod-sensitive genotypes, these hybrid sorghums have extended periods of vegetative growth and do not flower under normal production practices (Bean et al. 2003). Rooney and Aydin (1999) demonstrated the vegetative growth stage can be extended from a typical 50 to 70 days for photoperiod-insensitive sorghum up to 170 to 180 days for photoperiod-sensitive sorghum. This extended growing period results in the maximum amount of plant material being produced, greatly increasing per acre yields of biomass. The longer vegetative growth stage also allows for a higher degree of drought tolerance due to the fact that most sorghum is more resistant to drought during the vegetative growth stage (Blumenthal et al. 2007).

Avant (2009) indicates high-energy sorghums are capable of producing 15 to 20 dry tons/acre of biomass under favorable growing conditions, while Rooney (2010) and Blumenthal (2010) are more guarded in their projections, speculating yields of 10 to12 dry tons/acre may be more realistic expectations in the short run. Rooney (2010) realized yields of 10 to 11 dry tons/acre on non-irrigated research plots in the Brazos River bottomlands of Texas. Trials conducted in the Texas Panhandle by McCollum and Bean (2007) reported heights of irrigated photoperiod sensitive sorghum ranging from 9 to10 feet and yields as high as 31.22 tons per acre harvested at 65 percent moisture (nearly 11 dry tons per acre). The biomass produced by these sorghums is primarily made up of the structural carbohydrates hemicellulose, cellulose, and lignin, making them ideal biomass feedstocks for use as a bioenergy crop. Analyses conducted by Blumenthal et al. (2007) estimated the composition of these sorghums to be: 26.3 percent hemicellulose, 29.3 percent cellulose, and 7.6 percent lignin. The growth habits and structural composition of HES produce an efficient, high-yielding biomass feedstock that can reduce land acreage dedicated to biomass and increase the conversion efficiency of biorefineries (Avant 2009; Blumenthal 2010; Rooney 2010).

Switchgrass Characteristics and Production

SG is a perennial C4 grass native to North America that is characterized by high-yielding potential and a tolerance to water and nutrient deficits (McLaughlin, Samson, and Bransby 1996). SG is adaptable to many soil types and can be grown in areas that would not support the production of many other crops. There are many varieties of SG and each can be classified into two main groups: upland or lowland. Upland types have a higher level of cold tolerance, are shorter (growing up to eight feet), are more drought tolerant, and generally yield less (four to six tons/acre/year) than lowland types. Lowland types are taller (growing up to nine feet), grow faster, yield more (six to eight tons/acre/year), and have a more prevalent bunch-grass growth habit than upland types. Matching the genotype, variety, and morphological type to the environment is very important to assure a lasting stand and to maximize the productivity of SG cultivators (Cassida et al. 2005;

Bransby 2008). The expected yield for SG is highly dependant on the region of production.

The costs associated with SG production includes three major components: (1) establishment, (2) reseeding, and (3) annual management. A reliable and commonly recommended planting date for SG is three weeks before or after the region's recommended maize (i.e., corn) planting date using conventional or no-till practices (Mitchell, Vogel, and Sarath 2008). SG is generally seeded at a recommended rate of five to 10 pounds of seed per acre (Bransby 2008). SG stands may take three or more years to become fully established and it remains productive for about 10 years. Nitrogen fertilizer is normally not applied during the initial establishment year as it tends to promote weed growth more than SG growth. Atrazine is a commonly-used herbicide for weed control and it often aids in SG establishment (Mitchell, Vogel, and Sarath 2008).

The productivity of SG stands is highly dependant on the amounts of nitrogen and water available to the plants, but SG exhibits little or no response to potassium and phosphorus applications (Sokhansanj et al. 2008). A one-year study conducted in Stephenville and Beeville, Texas, indicates the optimum amount of nitrogen for Alamo SG managed for biomass was 150 pounds per acre with a resulting biomass yield of 6.47 tons per acre in Stephenville and 4.77 tons per acre in Beeville (Mitchell, Vogel, and Sarath 2008). The timing and frequency of harvest also plays an important role in SG biomass yields. Alamo SG field trials were conducted by Sanderson, Reed, and Reed (1999) in Dallas and Stephenville, Texas, to evaluate this relationship. The four-year study (1993-1996) determined that multiple-harvests during the year reduced total annual biomass yields. In Stephenville, increasing harvest frequency from one to four cuts decreased annual biomass yield by more than 50 percent. Annual biomass yields were maximized when harvest frequency was reduced to once per year (Sanderson, Reed, and Reed 1999).

The most favorable time to harvest SG is two to three weeks after a killing frost as this promotes nutrient recycling for winter storage. Delaying the SG harvest until the following spring to allow for "Just-In-Time" delivery can result in a dry matter loss of 20 to 30 percent, but further promotes nutrient recycling and reduces the ash content of the biomass (Blade Energy Crops 2009). The moisture content of SG harvested in the late-summer is greater for lowland varieties than for upland types; normally around 45 percent and 39 percent, respectfully. Biomass harvested in the late-autumn generally contains about 35 percent moisture content while overwintering SG for harvest the following spring will further decrease moisture content to about seven percent (Blade Energy Crops 2009).

The moisture content of harvested SG can be reduced by mowing the crop and allowing it to field dry. A study conducted by Sanderson, Reed, and Reed (1999) reported that the moisture content of mowed SG declined from 43 percent to 10 to 17 percent in three to seven days, depending on weather conditions (Sokhansanj et al. 2008). Moisture content during storage is also an important factor as excess moisture can cause damage and loss of dry matter. Dry matter loss in round bales stored outside for nine to 11 months has been reported to average 3.4, 7.7, 8.3, and 14.9 percent for bales wrapped with plastic film, net wrap, plastic twine, and sisal twine, respectively. Bales stored indoors had an average dry matter loss of three percent (Sokhansanj et al. 2008). Assuming an 11-month storage period, such loss estimates translates into 0.3, 0.7, 0.75, and 1.35 percent per month for bales stored outdoors and wrapped with plastic film, net wrap, plastic twine, and sisal twine, respectively, and 0.27 percent per month for bales stored indoors.

Biomass Conversion Technologies

The three principal biomass conversion technologies currently being considered to convert biomass into energy are thermo-chemical conversion, biochemical conversion, and physico-chemical conversion. These three technologies all possess limitations and require further research and development to become economically competitive (Comptroller's State Energy Conservation Office 2008).

Thermo-chemical conversion processes treat biomass under high levels of heat in the absence or presence of an oxidant (oxygen) and include: pyrolysis, gasification, and combustion. Pyrolysis is the thermo-chemical conversion process of biomass in the absence of an oxidant. This process produces medium calorific value gas (MCV) or syngas, liquid condensates such as bio-oil, water, and tar, and "char," which is a carbonaceous solid product with more than two percent carbon. Gasification is the thermal conversion of biomass in an oxygen-deficient environment and produces similar products as those realized using pyrolysis conversion. Combustion involves the burning of biomass in the presence of oxygen to produce heat, electricity, or mechanical power. The syngas produced from using either pyrolysis or gasification conversion processes can be converted into synthetic gasoline or diesel fuels either catalytically or by using steam to produce gas or diesel (Comptroller's State Energy Conservation Office 2008).

Biochemical conversion processes convert biomass into high-energy liquid (ethanol) or gaseous compounds (methane) by employing specific microbial populations. Anaerobic digestion for biogas production and fermentation used for ethanol production are two processes included in this category. Anaerobic digestion uses the enzymes from acid-producing microbes to break down cellulosic biomass compounds into organic acids which are converted into methane by using methane producing microbes. Ethanol fermentation involves the use of amylase-producing microbes to break down the starchy materials found in cellulosic biomass to sugars and then uses yeast to convert the resulting sugars into ethanol (Comptroller's State Energy Conservation Office 2008).

Physico-chemical conversion involves the transesterification of fats and oils from biomass and is noted as the simplest process to produce liquid transportation fuels. Refined, bleached, and deodorized vegetable oils or animal fats are mixed with an alcohol (most commonly methane) in the presence of a base or acid catalysts such as sodium methoxide. The resulting product produced from this process is esters of oil or biodiesel (Comptroller's State Energy Conservation Office 2008).

Literature Review Summary

The literature review presented above leads to two conclusions regarding the current state of cellulosic biomass feedstock research: (1) a consensus is reached that the logistics costs associated with cellulosic biomass feedstock production must be reduced for cellulosic biofuels to be a competitive source of fuel, and (2) few studies that link the logistics operations for high-energy sorghum, SG, and alternatives to these sources into a single microeconomic study have been or are being conducted. These observations provide the motivation for the research reported in this thesis.

RESEARCH PARADIGM

The research paradigm explained in this thesis is a hypothetical corporate biomass feedstock farming entity (CBFFE) located in the Middle Gulf Coast, Edna-Ganado, Texas area (figure B2) supporting a bioenergy conversion facility. Centralized corporate management handles all production, harvesting, transport, and storage operations for HES and SG. The CBFFE operation is separate from the bioenergy conversion facility and relies on an extended contract and arrangement with the conversion facility for its sale of delivered biomass feedstocks. Therefore, individual farmers are not responsible for growing, harvesting, or transporting the energy crops from the field to storage or to the conversion facility; instead, the corporation hires labor to operate its machinery and equipment and to perform field and delivery operations.[15]

Land is cash leased by the corporation for an extended period of time (e.g., 10-15-20 years) at a rate that provides an incentive to landowners to switch current use of their land from other production practices (assumed to be mainly pasture or abandoned rice land) (Raun 2010; Popp 2010) to energy crops. It is presumed a cash lease rate substantial enough to move land from contemporary rice or row crop production to energy crops is not financially or economically feasible, given current HES production yield and harvesting technologies (Falconer 2010; Blumenthal 2010). A rotation pattern of one year of HES followed by two years of fallow/pasture is used for this analysis.

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[15] Sensitivity analyses are used to evaluate economies of size for such a corporate structure versus several smaller farming operations being used to supply biomass feedstocks to the bioenergy conversion facility.

During years HES is not grown, the land is subleased by the corporation to local producers for use as pasture so as to minimize the net rental cost of land farmed in HES.[16]

All machinery and equipment used for the production of HES is assumed purchased by the CBFFE in this analysis. The structure of Sorghasaurus© allows for leasing of machinery and equipment, but this feature is not utilized in the baseline scenario application of the model[17]. A fleet of machinery that moves across the Southern U.S. and could be leased on a short-term basis (e.g., similar to contemporary leasing of combines for rice and/or other grain harvesting) would significantly reduce the capital cost for energy crop production, but no such system is currently in place.[18]

Custom-hire machinery and equipment is assumed available for the establishment of SG acreage in this analysis. Annual maintenance and mowing-raking-harvesting-transporting operations are assumed to be performed with CBFFE-owned machinery and equipment.

HES is assumed to be green chopped and either delivered to storage (located at/near the conversion facility) or delivered directly to the conversion facility "Just-In-

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[16] Sensitivity scenario 9A was used to evaluate the consequences of realizing higher-than-expected returns on HES land during the two years it is not planted to HES in the rotation cycle.

[17] Sensitivity scenario 5J was used to evaluate the consequences of assuming requisite transportation trucks and trailers could be leased instead of needing to be purchased.

[18] If biomass feedstock production technology and related logistics were to be economically competitive (or approach such a position), there may exist the potential to perhaps link several conversion facility operations with varying critical demand periods for select machinery and equipment along a geographic corridor; thus, providing opportunities for allowing such machinery and equipment to be shared across operations during the calendar year and thereby lower requisite capital ownership costs.

Time."[19] SG land is not rotated with other crops; rather, it is a perennial crop and is hence continuously "farmed" and subject to being harvested once every year after establishment on an as needed basis. SG is used to supplement the conversion facility's biomass feedstock needs during periods of no or low HES production[20]. SG is left in the field until it is needed by the conversion plant and then is delivered "Just-In-Time."[21]

Alternative biomass feedstocks (e.g., wood chips) to HES and SG may also be available to supplement the conversion facility's biomass feedstock needs. The

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[19] "Just-In-Time" delivery should be interpreted to mean that the exact amount of biomass feedstock required by the conversion facility to meet periodic requirements is delivered to the conversion facility and no excess biomass feedstock is transferred from period to period. Although SG, purchased-transported alternative biomass feedstocks, and purchased-delivered alternative biomass feedstocks are theoretically used supplemental to HES and delivered "Just-In-Time," these biomass feedstocks could possibly be stored and transferred from period to period if desired by adjusting the model-user-specified right-hand side constraints of the analytical model.

[20] A risk management strategy using SG biomass feedstock is incorporated to minimize the risk of not meeting conversion facility periodic requirements. This strategy involves producing an extra 25 percent of the conversion facility's annual requirement in SG. It is assumed this extra SG acreage is not harvested in the economic analyses of this thesis, but rather represents "stored-in-the-field' biomass feedstock that constitute an insurance policy against crop failure and transport or delivery problems, thereby assisting in assuring availability of year-round biomass feedstock supplies to the conversion facility. Establishment and normal annual maintenance costs (e.g., fertilizer, herbicides, etc.) for SG acreage are accounted for in the analysis. It is assumed such acreage is sublet for grazing (for annual $5/acre) for three months (December-February) each year following the conclusion of the HES harvest season.

[21] Another alternative to producing SG for non-HES periods and/or as an insurance strategy would be to purchase hay from area producers (Falconer 2011). The inclusion of SG production rather than reliance on area Coastal hay supplies is predicated on several factors:

- Initial interest in establishing the cost for a self-sufficient entity supplying the conversion facility, (i.e., subsequent research can explore the merits of Coastal hay as an insurance strategy);
- The model used in this thesis research, Sorghasaurus©, is capable of facilitating such evaluations due to its inclusion/consideration of activities that allow for the acquisition/purchase of non-entity produced sources of biomass feedstocks;
- Falconer has Coastal hay enterprise budgets which suggest apparent costs in the magnitude of $73 per ton based on edge-of-field production costs up to $100 per ton based on selling price opportunity costs for such hay as a potential biomass feedstock source (Falconer 2011). Further, he suggests there is probably adequate hay storage resources in the area to facilitate using coastal hay as an insurance strategy; but
- It must be recognized that there is limited objective knowledge of (1) the existing hay market in the area and (2) the responsiveness/capability of area producers to supply requisite quantities inasmuch as needed times for such would probably correspond to production issues in the hay sector similar to HES and SG production problematic issues.

availability and cost (i.e., total of purchase and transportation/ handling) of most alternative biomass feedstocks inhibits reliance on their year-round use as an economically-viable alternative to produced crops during their harvest periods. Alternative sources could be used, however, to provide a cushion in periods when HES and SG production are low to assure that the cellulosic conversion plants needs are met during each period[22]. The logistical scheme for the total production-harvest-transportation-storage-alternative sources of biomass feedstocks paradigm for supplying the conversion facility is illustrated in exhibit C2.

[22] It is assumed that the conversion will operate 24 hours a day and 365 days a year. Thus, enough biomass feedstock must be delivered "Just-In-Time" or be in storage to meet the conversion facility's biomass feedstock needs on a daily/hourly continuous basis. As noted previously, the economic feasibility of such alternative sources of biomass feedstocks, although facilitated within Sorghasaurus©, are not addressed explicitly in this thesis research. This issue is noted subsequently as an area of need for future research.

METHODOLOGY

The holistic logistics costs associated with supplying a bioenergy conversion plant with biomass feedstock is the basic issue addressed in this research. For the purpose of this research, "logistics" is interpreted to include all of the operations required to grow, harvest, and transport the biomass feedstock from the production area to the conversion facility, including any intermediate and final on-site storage, as well as guarantees[23] the delivered biomass feedstocks meet the specifications of the conversion facility on a continuous, uninterrupted, hourly basis throughout the year.

Deemed necessary for achieving the aforementioned objectives is development and use of a cost minimization linear programming model (Sorghasaurus©) to integrate capital budgeting, annualized costs, and crop enterprise budgeting, providing for an integrated optimization analysis of the production, harvesting, transporting, and storage of alternative biomass feedstocks. Capital budgeting and enterprise budgeting provide life-cycle cost information for use in the linear programming model.

Capital Budgeting

The appropriate method for evaluating a capital project is to apply economic and financial procedures toward identifying life-cycle costs for capital investments. **Capital Budgeting** involves the analysis of investment projects by evaluating the net cash flows

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[23] As detailed subsequently, two forms of biomass feedstock supply insurance are incorporated into the holistic logistics of the supply chain for the conversion facility.

generated by investments over their entire economic life (Penson and Lins 1980). To analyze each project, it is necessary to know (1) the initial cost of the investment, (2) the annual net cash revenues/expenses realized, (3) the expected life of the investment, (4) the reinvestment by time frame, (5) the salvage value, and (6) the discount rate to be used:

$$AEV = \left\langle \left[\left(\left(\left(PP + M + I + PT \right) \div SV \right) \div \left(1 + r \right)^{UL} \right) \div \left(1 - \left(1 - r \right)^{UL} \right) \div r \right] \right\rangle$$

where,

AEV: annuity equivalent value;

PP: purchase price;

M: annual fixed cost for maintenance;

I: annual fixed cost for insurance;

PT: annual fixed cost for property taxes;

SV: salvage value;

r: discount rate; and

UL: useful life.

Standard Capital Budgeting (i.e., **Net Present Value** (NPV)) analysis is used in this research along with the calculation of life-cycle **annuity equivalent** values (Rister et al. 2009) to determine the economic feasibility of biomass feedstock production. Standard NPV analysis allows for comparison of uneven flows of money among alternative investments. Annuity equivalent calculations extend the standard NPV analysis to allow comparisons of projects with different economic lives (Rister et al. 2009; Sturdivant et al. 2008; Rogers 2008; Boyer 2008).

Enterprise Budgeting

Enterprise budgets allow managers to compare cost and returns of alternative crop or livestock activities and evaluate the technology, resources, and management practices used for each option. An enterprise is an unit of economic organization specifically designed for business use. The primary purpose of enterprise budgets is to estimate the costs, returns, and profit per unit for each enterprise (Kay, Edwards, and Duffy 2003). Exhibit C3 is an illustration of an enterprise budget for rice in the targeted Middle Gulf Coast, Edna-Ganado, Texas study area of this thesis research (Texas AgriLife Extension Service 2010). Such a budget is a valuable planning tool for business managers and provides a means of estimating and comparing the profitability of different enterprises and management strategies. Crop enterprise budgets developed in this research are the building blocks for annual activities in the linear programming model.

Linear Programming

Linear programming (LP) is a quantitative research technique that minimizes or maximizes an objective function by allocating scarce resources across multiple alternatives in the most-economical manner (Beneke and Winterboer 1973). LP models provide an effective tool for analyzing a variety of economic decisions such as crop selection, transportation, budgeting, and firm-level management problems, as well as facilitate an unbiased analysis of the problem, subject to resource availability.

There are three fundamental elements that comprise an LP model. The first element is the objective function which, when optimized, selects the optimal solution from a universal set of specified possible solutions. The decision variables comprise the second component. Decision variables indicate the unknown quantity of each respective specified decision activity available to optimize the solution. The final elements of a LP model are the constraints. The constraints are restricting in that they specify the amount of each resource that is available or the upper limit of the resource and can also specify the minimums and maximums for specific activities as well as establish relationships among decision variable activities (Parker 1985; McCarl and Spreen 2003). Mathematically (Agrawal and Heady 1972),

$$\textit{Minimize } Z \sum_{j=1}^{n} c_j x_j \qquad \text{subject to}$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$x_j \geq 0$$

where,

a is an m x n matrix of technical coefficients, c is an n x 1 vector of prices or other weights for the objective function,

x is an n x 1 vector of activities (commodities to produce),

b is an m x 1 vector of resources or other restraints,

cx = Z is the objective function, and

i = 1, 2, . . . , m; and j = 1, 2, . . . , n.

Several examples of previous research utilizing LP are discussed next to establish the basis for the approach used in developing Sorghasaurus©, the LP model used in this thesis research. A study conducted by Popp, Nalley, and Vickery (2010) employed a LP model to examine how county net returns to crop production are affected by restricting irrigation in the Alluvial aquifer to more sustainable levels and how crop allocation might change if a market existed for less water-intensive crops such as SG and forage sorghum. The LP model used in this study tracks crop profitability and resource use so producer behavior could be modeled on a county-by-county basis.

McCarl et al. (2000) used LP to analyze the agricultural operations component of the Texas Department of Criminal Justice (TDCJ). The TDCJ agricultural operations is highly diversified and vertically integrated, comprised of vegetable and field crops plus several livestock enterprises and processing facilities located at numerous locations across Texas. PRISAG is an LP model developed to facilitate evaluation of the merits of continuing the agricultural operation. PRISAG-MIP, a mixed-integer extension of PRISAG, was used to account for the discrete (0,1) nature of capital investments associated with continuance of the TDCJ agricultural operations. In McCarl et al. (2000), PRISAG and PRISAG-MIP are applied to identify the consequences of alternative realignments of major components of the TDCJ agricultural operations, demonstrating the associated potential economic consequences thereof. Ward et al. (1998) also used the PRISAG model to identify the effects of imposing system-wide, “across-the-board,” budget cuts without regard to the efficiencies of distinct sub-components of the system. The various linkages among the TDCJ agricultural operations sub-components facilitated representation of the intrinsic interactions not apparent in more simplistic enterprise budgeting perspectives.

Stokes et al. (1998) used a mixed-integer form of a LP model to investigate the operations efficiency of the Texas Department of Criminal Justice (TDCJ) swine packing plant (SPP). Goal programming was incorporated with the SPPs schedule to identify optimal operations patterns which were subsequently used by management to identify both strategic capital investment opportunities and tactical operations decisions.

Miller et al. (1990) used LP modeling in conjunction with enterprise budgeting to evaluate government farm program participation decisions. The advantages of being able to consider total farm impacts of such decisions, including the consequences of payment limitations, in contrast to traditional partial analysis of a single acre either in or out of the program and for owner/operator versus tenant farmer and landowner scenarios, were demonstrated.

Griffin et al. (1988), while investigating the economic merits of replacing flood irrigation with sprinkler irrigation for Texas rice, used LP and capital budgeting to identify the net present value of the two alternatives. The Technical and Economic Assessment Model for Alternative Rice Cultures (TEAMARC) model represented capital investment decisions, machinery and labor contributions to periodic field operations, and acquisition of variable inputs, while also reflecting constraints on machinery, labor, and irrigation water resources. Timeliness of field operations and ensuing impacts on harvested yields were reflected in the design of TEAMARC. Crop rotation considerations between rice and soybeans were also represented in TEAMARC.

Whitson et al. (1981) used LP in conjunction with machinery capacities and trafficable field day estimates to examine crop diversification and capital investment decisions. Weather risk and its effects on trafficable field days were demonstrated to be substantially influential in determining optimal profit-maximizing decisions at the firm level.

Lacewell and Masch (1972) applied LP to estimate the response of production agriculture to chemical taxation (expressing social costs in the cost function) and setting a marketing quota on quantity. This research suggests incorporating social costs associated with alternative pesticides into the farmers' objective function equations.

Lacewell and Grubb (1971) developed a LP model to estimate the temporal economic optimal water use for irrigation from the Ogallala Aquifer, which is exhaustible. Since irrigation water is exhaustible and is the most limiting of the scarce resources over time, the economic objective for a producer is to maximize the present dollar value of the exhaustible water resource. The model was developed to estimate how much water to use each year and include capital-valuation estimates for the firm.

Whitson et al. (1973) addressed the decision complexity facing wheat farmers. This study was an evaluation of grazing wheat for alternative periods, with recognition of the accompanying impacts on grain yield, all the way to grazing until there was not a harvest for grain. Further complicating the decision environment was compliance with the Federal Farm Program and meeting an acreage set-aside requirement. The results were of value to wheat farmers as well as the federal government since they provided insight on farmers' reactions to proposed changes in the federal farm program.

Hardin and Lacewell (1979) developed a model for maximizing annual net returns (returns to land) for an irrigation farm on the Texas High Plains. The model included major crops produced in the region, i.e., corn, sorghum, soybeans, cotton, and wheat plus a grazing option on the wheat with options of irrigation or rainfed (dryland) production. Crop enterprise budgets were applied to populate the LP model along with yield data based on alternative irrigation levels using statistical production functions. The overall purpose of the study was estimating the effect of improved irrigation well and pump efficiency on present value of returns to groundwater over a 20-year period.

Laughlin and Lacewell (1981) evaluated the crop yield and economic implications of a Corps of Engineers salinity control program for the Red River. The study used linear programming to estimate the agricultural benefits associated with alternative chloride control options and with alternative irrigation technologies (i.e., furrow, border, or sprinkler). Water required for irrigation was a function of the specific crop and also the level of salinity since a leaching fraction was required. In addition, the impact of chloride level was reflected in crop yields, even with a leaching fraction. The model was a recursive linear program with Fortran components and a matrix generator to develop a unique enterprise budget for each combination of crop, soil type, irrigation system and zone in the river reach. The model contained more than 8,000 activities and had a report writer attached to simplify results reporting.

There are numerous other studies that have applied LP to a multitude of issues to gain insight. Additional applications of LP are reported by Lacewell and Condra (1976); Lacewell, Jones, and Osborn (1976); Condra and Lacewell (1977); Zavaleta, Lacewell, and Taylor (1979); Petty et al. (1980); Muncrief et al. (1983); Ellis et al. (1990); and McCarl, Jones, and Lacewell (1997).

Methodology Summary

The collective use of linear programming, capital budgeting, annuity equivalent values, and enterprise budgeting represents a holistic paradigm to use in evaluating a complex set of alternatives and goals affected by a myriad of constraints and linkages among the alternatives. The linear programming model developed in this research project, Sorghasaurus©, is a robust, multiple-period model capable of evaluating a cost-minimizing production, harvesting, transportation, and storage of biomass feedstocks system with a variety of alternative biomass feedstocks available. This inaugural application of Sorghasaurus© is focused on the Middle Gulf Coast, Edna-Ganado, Texas area, but the model is flexible enough in its design that it can be applied to other regions. Such extension of the model's use can be accomplished by adapting the data used in the model to reflect the production practices, technology, and resources used in that specific region along with possible structural changes in the model if necessary.[24]

[24] Extending the application of Sorghasaurus© to the Rio Grande Valley of Texas, for example would incorporate into the analyses consideration of ratooning opportunities for HES, an additional type of biomass feedstock production – miscane (da Silva 2011; Jifon 2011; Sturdivant 2011), and sharing of harvest and transportation resources with the RGV Sugar Growers, Inc. sugar mill at Santa Rosa.

DESCRIPTION OF SORGHASAURUS©

Sorghasaurus© is a cost-minimization linear programming (LP) model intended to provide a realistic representation of the holistic logistics costs associated with supplying a 30-million gallon (annual) biomass conversion facility with alternative cellulosic biomass feedstocks[25]. The LP model is constructed in Excel and is comprised of 15,944 columns and 2,213 rows. The Excel add-in What's Best, developed by Lindo Systems, Inc., is used for optimizing the model[26]. Sorghasaurus© is set up on a pseudo-bi weekly basis (i.e., two periods per month, totaling 24 time periods for the year) and divided into 15 major segments:

- Financing Activities for Operating and Capital Investment Dollars;
- Headquarters;
- Land: HES and SG Leased Lands, and Purchased Land for Storage and Headquarters;
- Machinery: Purchased and Leased;
- Labor: Full-Time and Part-Time;
- Irrigation: Irrigation Wells, Pumping Groundwater, and Purchasing Surface Water;
- HES Field Operations;

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[25] Note the size of the conversion facility is an input parameter easily modified in the model.
[26] The assistance of Mark Wylie of LINDO Systems, Inc. and Bart Basile, computer technician in the Department of Agricultural Economics, Texas A&M University, in facilitating the installation and successful implementation of these software packages is gratefully acknowledged.

- Close Land Loop: Transfers land out of last field operation and supplies it for the following year's production;[27]
- SG Field Operations;
- Transportation: HES, SG, and Transport Purchased Alternatives;
- Storage Adjacent to the Conversion Facility;
- Storage Temporal Transfers;
- Cellulosic Conversion Facility's Bi-Weekly Biomass Feedstock Requirements;
- Transfer Tractor Hours: Allows selection by tractor size and hours to be used for several field operations to minimize capital investment cost; and
- Overhead Management and Support Staff.

An introduction of the structure's of Sorghasaurus© is presented in table A3. Then details are given in tables A4a - A4g. The 15 segments noted above have related costs[28] and constraints (e.g., maximum hours of labor available each period) which, when considered with the model's global objective function, allows application of the Sorghasaurus© model to identify the cost-minimizing combination of activities. A description of each segment and how the segments work together to represent a realistic, holistic production-harvesting-transporting-storage biomass feedstock supply system are described below. Additional details regarding the specifics of the modeling components

[27] The close loop feature allows for the temporal flow of field activities in a steady state sense.
[28] Both capital fixed and operating variable cost are considered.

encompassed in Sorghasaurus© and the associated requisite data used in the baseline analysis are presented in Appendix D.

The multiple-period structure of Sorghasaurus© allows for (1) flexibility in customizing the model for specific geographic regions; (2) defining a sequence of required field operations according to local conventions; (3) spreading of performance of individual field operations across two or more time periods, and (4) accounting for the desired likelihood of trafficable days on a seasonal/periodic basis, thereby allowing for minimization of overall annual equivalent costs to deliver. The model allows users to designate (1) the required field operations; (2) in a definitive sequence; and (3) specify in which time periods each such operation may occur.

Capital Resources

Two financing (i.e., dollar) resource rows are used to monitor available supply and demand for capital investment and operating monies (table A4a). These rows allow the model user to specify the dollars available for capital investments and operating expenses by adjusting the Right-Hand Side (RHS) constraints with the effective constraint signs being less than or equal to a specific value. If sufficient funds are not provided by the user in terms of the specified RHS constraint levels to cover requisite capital investment and operating expenses, dollars are borrowed at a specified interest rate (e.g., set available operating funds at $0 in the RHS constraint) to allow Sorghasaurus© to internally calculate opportunity interest cost on operating monies used in the optimal solution. In this thesis research, a capital discount rate of 5.75 percent (Lacewell 2010) and an operating expense interest rate of 6.125 percent (Rister et al. 2009) are assumed. This technique captures the interest expense (1) to reflect capital opportunity cost and/or (2) cash interest in the event a loan must be acquired.

Headquarters

The headquarters (HQ) for the CBFFE is comprised of office buildings, pole barns for outside machinery storage, enclosed barns for inside machinery storage, and road base for parking. A resource row is used for each of these components to determine the square footage required, based on model-user-specified variables and supplied by capital purchase activities (table A4a).

The amount of office space needed is calculated based on the number of acres in production, i.e., the larger the leased land (acres), the greater the amount of required office space. Sorghasaurus© relies on model-user-specified machinery dimensions to determine the square footage required for pole barns and enclosed barns for inside machinery storage. Road base is used to cover the ground in both types of barns and for a parking lot. Since the office building will have a concrete slab, no road base is needed for that square footage. Thus, the amount of road base required is determined as the total headquarters land area minus the square footage of the office building. Determined within Sorghasaurus© is the total amount of land required for the headquarters based on a model-user-specified proportion of the square footage required for office buildings, pole barns, and enclosed barns for inside machinery storage (i.e., double or triple the `amount space needed for office buildings, pole barns, and barns for inside machinery storage).

Land Resources

There are two types of land resources specified in Sorghasaurus©: (1) leased land resources, and (2) purchased land (table A4a). Leased land activities are used to supply acreage to the HES and SG field operations, while the purchased land activity supplies land for the CBFFE headquarters and storage center. Leased land restricts or limits the amount of acreage available for HES and SG production by using less than or equal to supply constraints. These resources can also be set to constrain the land resources to consist of certain characteristics by adjusting the lease price to reflect the desirability/productivity of the land. Three leased-land resource types are utilized for HES to allow for different cash rental rates, but the assumption is made in this thesis research that land is homogenous and no yield gains are realized by leasing higher-valued land. This assumption is made because HES and SG yield curves for different land classes have not been established nor are they represented in Sorghasaurus©[29]. A land transfer option is utilized for HES and serves to transfer cash rented land to the first HES field operation represented in Sorghasaurus©.

Minimum and maximum leased land resource acreage constraints are modeled for SG. This modeling approach allows the model user control over SG production, facilitating design of sensitivity scenarios to answer "what if/then" questions. SG land is

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[29] The lack of agronomic information as to how HES and SG yields react to different land qualities is one factor limiting the use of multiple yield curves for different land classes. Another factor is that there are not enough columns available in Excel 2007 (Walkenbach 1996) to include this feature. If multiple yields curves are to be included, either the Excel LP period model would need to be transformed in to a dual representation or the GAMS optimizing program (Brooke, Kendrick, and Meeraus 1986) would need to be used.

transferred to the establishment operation similar to the method used for HES and then activities are used to capture annual production and harvesting operations.

The quantity of purchased land available for the headquarters and storage center is not restricted. Instead, the constraints are set to greater than or equal to zero so either the exact amount or more than the amount of acreage[30] required by each segment based on the model user's specifications is supplied.

Machinery and Equipment Resources

Two means of acquiring machinery and equipment for performing HES and SG field operations, harvesting, storage, and transportation activities are incorporated into Sorghasaurus©: (1) purchase, and (2) lease (table A4a). Annuity equivalent annual ownership costs (including insurance, property taxes, and fixed repairs) are identified for the purchase alternatives and hourly lease rates on a bi-weekly schedule are used for the leasing alternatives. Purchasing machinery supplies trafficable hours[31] in each of the 24 time periods comprising one complete annual cycle, whereas leased machinery is rented on an hourly basis for each specified time period independent of leased machinery for the other time periods.[32]

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[30] In actuality, the model will solve with the minimum acreage required (since the objective is to minimize cost) and there will be no surplus or slack acreage leased.

[31] The exact number of hours supplied each period is a function of total hours available during the period, assumed length of workday, and model-user-selected probability of field conditions being suitable for field work, i.e., "trafficable."

[32] That is, there are 24 leasing activities for a specific capital asset (e.g., a tractor) whereas there is only one purchasing activity for that same asset.

Twenty-five resource sections[33] (pieces of machinery and equipment) are employed for the purchase alternative which represent all machinery and equipment resources available for HES and SG production, harvest, transportation, and storage operations. The model user has the option to specify bi-weekly trafficable[34] hours which are used along with machinery capacities and annualized ownership costs in conjunction with HES and SG harvest yield curve information to determine the required number of machinery units for performing each alternative operation within the specified range of allowed time periods.[35]

Since machinery and equipment may also be leased on an hourly basis, Sorghasaurus© includes an option for the user to set the constraints to represent the hours available for lease for each of the 25 leased machinery resource sections. The hours available for lease per unit of machinery/equipment leased in a particular period are assumed to be the same as the number of trafficable hours for the period in that such leasing activities supply HES and SG production, harvesting, storage, and transportation operations with machinery and equipment hours.[36]

Hours per acre machinery capacities are used for all HES and SG field operations and harvesting, while hours per ton machinery capacities are used for

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[33] These twenty-five (25) sections are different than the 24 bi-weekly time periods. The 25 sections represent the 25 different and distinct pieces of machinery and equipment that can be purchased for use.
[34] "Trafficable" is intended to mean that machinery/equipment can be driven over the fields (i.e., the fields are not too wet for the equipment to operate).
[35] Trafficable hours are determined by multiplying daily work hours by trafficable days and are used to account for weather delays, providing the amount of hours during each period that field operations can occur (Parker 1985).
[36] Lease hours are directly based on machinery/equipment hours of use in excess of available owned machinery/equipment hours.

transportation and storage-handling machinery requirements. These machinery capacities represent a machinery hour and the numbers of acres or tons for a particular logistic operation that can be completed during that hour. As land is supplied for field operation activities and biomass feedstocks are transported and stored, machinery hours and trafficable days are used. Determined within Sorghasaurus© are the number of machinery hours required to perform the field operations, storage, and transportation activities in an allowable time period and then, by using trafficable hours (i.e., hours available each period for performing the operation), and costs thereof in combination with yield tradeoffs associated with when field operations and harvesting occurs, the model determines the required number of machinery units. Thus, machinery capacity requirements for each field operation compete for a limited number of trafficable hours during each time period.

Labor Resources

Full-time labor and part-time labor resource availabilities and requirements are specified by the user in Sorghasaurus© (table A4a). All labor resources are specified on a bi-weekly basis, allowing the model user to set the hours available each period by adjusting the RHS constraints. Hiring a full-time laborer on salary supplies labor hours each time period even if not needed (i.e., there may be “slack”/surplus full-time labor hours for some periods). In contrast, part-time labor is hired on an hourly basis for each specified time period independent of part-time hires for other periods[37]. Full-time and part-time labor resources are pooled and made available for the HES and SG field operations, irrigation activities, harvesting, transportation, and storage operations. Assumed in Sorghasaurus© is that all full-time laborers are capable of performing all activities for which labor resources are required. Since part-time labor availability is specified on a per period basis, the model user has more control over the activities that these laborers can perform. This control is accomplished by making part-time labor available for hire only in the time periods during which the desired activities can be performed.

Irrigation Resources

Sorghasaurus© is designed to supply irrigation water for HES in the form of either groundwater and/or surface water. Since different well sizes are prevalent in the Middle Gulf Coast, Edna-Ganado, Texas area[38] for groundwater irrigation, three irrigation well resource options are available for purchase in the model (table A4b). RHS constraints for these irrigation options allow the user to specify the number of each size well that can be purchased. Pumping capacities for each well size are specified and, if purchased, the respective well sizes supply different amounts of ground water on a bi-weekly basis for irrigation.

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[37] Inasmuch as part-time labor is hired on an incremental, continuous hourly basis as long as no associated RHS values are set by the user at greater than zero, the optional solution should include hiring of part-time labor only when it is most economical to do so with no resulting excessive hiring.
[38] Presumably, such different well sizes are possible in other geographic regions for which Sorghasaurus© may be used.

Surface water is purchased on a per acre-inch basis, allowing the model user to specify the amount of surface water available for each of the bi-weekly periods. Once acquired, groundwater and surface water resources are transferred to a combined pool of irrigation water available for use. Applying groundwater and surface water to HES fields requires labor resources. These resource requirements are specified on a per acre-inch basis and can be satisfied with labor from either full-time or part-time resources, thus linking bi-weekly labor resources to irrigation activities.

Re-lift pumps are used to transfer irrigation water out of canal lateral systems and onto the HES fields for furrow flood irrigation. The number of re-lift pumps required is based on: (1) the total numbers of acres in production, and (2) the size of the fields. The required number of re-lift pumps are based on model-user-specified field size, i.e., one re-lift pump per field.

High-Energy Sorghum Field Operations

HES field operation activities are presented in table A4c. This table demonstrates how land flows through each of the 20 possible field operations. Also illustrated is how the planting and harvesting operations are “linked” together to facilitate use of a hypothetical HES yield curve reflecting subjective expectations regarding effects of timeliness of field operations (planting/harvesting dates combinations) on harvested yields.

Variable operating costs for each field operation are specified in the objective function and reflect the per acre variable costs associated with the production of HES.

These costs include fuel, repairs and maintenance, seed, fertilizer, herbicides, and pesticides. Included in Sorghasaurus© are 24 time periods the model user can set to represent available periods for performing each field operation. Such representation is accomplished by setting a high cost (e.g., $10,000 per acre) for the time periods in which a field operation should not occur, and setting the appropriate operating costs (e.g., $25 per acre) for the time periods during which the field operation can occur[39]. Methodical application of this technique for each of the 576[40] activities representing each designated field operation facilitates making the time periods available/unavailable according to appropriate agronomic and other considerations for the geographic region selected for analyses.

Sorghasaurus© is designed so land flows from the first model-user-specified HES field operation to the last model-user-specified HES field operation. This "linkage" feature prevents land from going backwards, skipping any field operations, or having the same field operation performed twice (i.e., this feature assures each designated field operation is performed only once, in the specified sequence, during the allowed time periods). The feature also facilitates consideration of yield tradeoffs occurring as a results of timely/untimely field operations relative to the capital ownership cost of machinery and equipment. Sorghasaurus'© design allows for up to 20 field operations, each of which may begin in any of the 24 bi-weekly periods and end in any of the 24 bi-

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[39] The "high" variable costs for selected time periods/field operations combinations will be avoided by the model as it seeks to minimize its objective function.
[40] For each of the 20 possible field operations, there are a maximum of 576 (i.e., 24^2) activities used to model the in-between operations and bi-weekly time periods.

weekly periods (as designated by the model user), allowing for maximum flexibility when setting time periods that field operations can occur.

As noted earlier, requiring the application of irrigation water on HES fields is incorporated into Sorghasaurus©. As groundwater is pumped and surface water is purchased, the two sources are combined into a common resource and then transferred for use on planted acres/fields. As HES acres move through the planting operation, post-planting periodic irrigation requirements must be specified by the user, thus tying bi-weekly irrigation resources to the planting operation. Sorghasaurus'© framework <u>does not</u> allow the model user to specify the possibility of alternative irrigation periods nor may the associated resulting impacts on harvested yields be represented (i.e., irrigation only occurs during deterministic post-planting periods specified by the user for each the planting period). Therefore, assumptions are made that irrigation happens on an "as needed basis" to provide adequate moisture to insure HES stand establishment and realization of the model-user-specified yields identified for each planting/harvesting time period considered (Blumenthal 2010).

An important feature of Sorghasaurus© is that the model user can specify hypothetical yield curves for HES, representing yields based on the combination of planting period and subsequent harvest periods (Rooney 2010; Blumenthal 2010). Sorghasaurus'© least-cost solution for supplying biomass feedstocks to the biomass conversion facility includes identification of the optimal periods to plant and harvest HES acreage based on the yield and numerous other related variables in the model, such as cellulosic plant needs during the respective periods, diversified periodic use of machinery capital investments, existing biomass feedstock supplies, costs of alternative biomass feedstock supplies, etc. Since these subjective yield curves are developed and used explicitly in the model, the planting field operation and harvest field operation must be linked to insure the appropriate yields are realized based on the respective planting periods. Therefore, these two operations (i.e., planting and harvesting) are set to "always" occur as HES field operation 11 (planting) and HES field operation 18 (harvesting). Up to seven planting periods are allowed to be specified in Sorghasaurus©. Each one of these planting periods is linked to a 576-column harvest section so yields for each harvest period can be obtained based on the yield curve and the harvested acreage can be transferred from appropriate prior-to-harvest field operation time periods and then on to the specified subsequent post-harvest field operation.

Close Loop Function

HES is an annual crop and all model-user-defined field operations must be performed each year. Therefore, if the crop is intended to be harvested continuously (i.e., every year) and/or the CBFFE's machinery and equipment resources are intended to be used in a "steady-state" sense, land must be transferred from the last field operation of the season back to (or fallow land being moved into rotation must be transferred into) the first field operation of the season to prepare it for next year's production. The "close loop" feature included in Sorghasaurus© facilitates this transfer, assuring a "steady state" of annual field operations. That is, a realistic annual production cycle is represented, constraining land that is moving out of the last field operation in year one such that it is only available for the first field operation in year two or in a later time period. This feature also prohibits machinery and equipment resources from being assumed to be used on both the current HES crop acreage and fallow land entering into the production cycle for the next year.

Switchgrass Field Operations

SG production operations and all biomass feedstock transportation activities are presented in table A4d. The method used to model SG production (table A4d) is greatly simplified compared to the method used for HES (table A4c). SG production activities are divided into: (1) establishment, and (2) grow and harvest. This simplified approach for representing SG is associated with it being a perennial crop with an expected productive life of 10 years per planted acre[41]. Annuity equivalents for a 10-year expected life are used in Sorghasaurus'© objective function to capture SG's establishment costs while variable operating expenses reflect the annual growing and harvest costs.

As SG land is acquired from the available SG leased land resources, it is transferred to SG establishment. All SG establishment operations are accomplished through hiring of custom operators; thus, no CBFFE labor or machinery resources are utilized for this activity. Once SG has been established, it is transferred to the growing and harvesting operations. These operations are not performed by custom operators, but

[41] As noted subsequently in the limitation section, the issue of expected production life for a SG planting is deserving of future research.

rather by the CBFFE, resulting in both CBFFE labor and machinery resources being used.

The Sorghasaurus© framework does not provide the same "linkage" feature for SG as is provided for HES. All SG growing and harvesting activities are compressed into a 24 activities bi-weekly section. Since SG is used to supplement HES biomass feedstock and is harvested on an "as needed basis", the model user is not permitted/required to identify time periods available for performing field operations. It is assumed SG growing and harvest activities are performed in a manner that allows maximum yield (possible within the confines of a subjective-estimated annual yield curves) to be harvested when needed by the conversion facility.

The model user is allowed to specify hypothetical yield curves for SG in Sorghasaurus©. These yield curves differ in comparison to HES yield curves in that they are not based on combinations of planting periods and subsequent harvest periods. This is largely due to SG being a perennial crop and planting not occurring every year. Instead, fixed yields are specified by the user for each of the bi-weekly periods based on growing season and time of year.

Besides the SG acreage that competes with HES acreage to supply the conversion facility year-round with biomass feedstocks, a risk management strategy is incorporated into Sorghasaurus© that establishes and grows additional SG acreage as an insurance strategy. Harvesting and use of this SG acreage is not accounted for in Sorghasaurus©, but rather the cost of establishing and maintaining the acreage is included to represent an insurance policy against HES crop failure and/or other problems in securing year-round supplies of biomass feedstock for the conversion facility. Inclusions and reflections of the costs for this “insurance policy” are accomplished by allowing the model user to specify an amount of acreage to be transferred to the establishment operation, but not to the SG field operations. It is assumed this insurance SG acreage is integrated into a five-year rotation with the production SG acreage, with 80 percent of the total SG acreage being harvested each year and the other 20 percent (representing the insurance SG acreage) laying idle. During the idled year (following harvest in the previous year), it is assumed the insurance SG acreage is not fertilized and not treated with herbicides[42]. For the purpose of the economic analyses in this thesis research, an annual credit (i.e., income) of $5 per acre is assumed to be associated with the leasing for grazing of this acreage during December through February. This revenue stream is incorporated into Sorghasaurus© as a reduction in the cash rental rate for SG land used for insurance.

Transportation

The transportation section of Sorghasaurus© represents the costs and machinery requirements for transporting all biomass feedstocks to the conversion facility or adjacent storage area (table A4d). Variable operating costs for transporting all biomass feedstocks are converted to a per ton basis and used in the objective function. Since operating costs

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[42] The concept of maintaining biomass feedstock acreage in an “insurance” context is absent in the literature. The assumptions made in this thesis research are elementary in nature, merely recognizing the probable need for such acreage and including what are more than likely low-side estimates of the costs for doing so. This topical area is deserving of additional research in the future.

are determined on a per ton basis (i.e., hourly operating costs divided by tons hauled per hour), per ton machinery capacities for semi trucks and storage handling equipment are also used to ensure a consistent unit of measurement.

HES is transported to storage on a wet basis (average 75 percent moisture content) since it is green chopped and then is converted into a dry basis at the conversion facility[43]. SG is transported on a dry basis because it is allowed to dry in the field after cutting and before being ”square” baled; thus, no moisture conversion is necessary. Transportation of HES and SG to storage or the conversion facility occurs simultaneously (i.e., same day) with harvest operations. Transfer activities are utilized that transfer the harvested HES and SG through the transportation section to storage or the conversion facility.

Biomass Feedstock Options

Alternatives to CBFFE-produced HES and SG biomass feedstocks can be acquired via activities incorporated into Sorghasaurus© which allows such alternatives to be purchased and used to meet conversion facility periodic requirements (table A4d). Alterative biomass feedstocks can be: (1) purchased and transported with company trucks as well as (2) purchased on a delivered basis, to the conversion facility. These features allow the model user to establish the appropriate amount of such alternative biomass feedstocks that are available each period for purchase and/or the amount of such externally-sourced

[43] As discussed subsequently, the costs of drying/removing the excess moisture at the conversion facility is ignored in this thesis research. Thus, it is deserving of future research.

biomass feedstocks that the conversion facility is willing to accept each period. The purchased alternative biomass feedstocks that must be delivered are transported to storage in much the same manner as HES or SG. The purchased and delivered alternative biomass feedstocks are transported directly to storage with no CBFFE semi truck machinery resources used.

A biomass feedstock tracking feature is incorporated into Sorghasaurus© to serve three major functions: (1) allow for the sizing of HES and SG biomass feedstock production operations, (2) track the amounts (i.e., tonnage) of biomass feedstock from all sources used to meet annual conversion facility requirements, and (3) facilitate the use of conversion efficiencies[44]. This "tracking" feature allows for the sizing of HES and SG biomass feedstock production operations according to the desired proportion of the conversion facility's annual biomass feedstock requirements. The model user can therefore set constraints to represent the required maximum and minimum amounts of HES and SG biomass feedstocks that must be produced annually to meet conversion facility requirements, which means more control over the amount of each biomass feedstock delivered to the conversion facility. Four resource constraints are used, two for HES (minimum and maximum) and two for SG (minimum and maximum) to incorporate this feature.

Since constraints are used to control the maximum amounts of purchased transported alternative biomass feedstock and purchased delivered alternative biomass

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[44] Although conversion efficiencies of alternative biomass feedstock could not be determined for this analyses, Sorghasaurus© provides a feature for them to be used in subsequent analyses.

feedstock available each period and thus, in effect, appropriately size these operations according to the model user's specifications, this "tracking" feature is only used to track the total amount of biomass feedstock transported or delivered of each. A final resource constraint is used to track the total amount of biomass feedstock from all four sources (i.e., HES, SG, purchased and transported, and purchased and delivered) used to meet annual conversion facility requirements. The constraint is set to equal the sum of the periodic requirements of the conversion facility.

This "tracking" feature also provides a mechanism to incorporate conversion efficiencies of the alternative biomass feedstocks into Sorghasaurus©. Conversion efficiency for this research is defined as the proportion of the biomass feedstock that can be converted into fuel. As biomass feedstocks moves into and through storage to the conversion facility, each individual biomass feedstock's conversion efficiency is accounted for and used to ensure that enough biomass feedstock is either purchased or produced to satisfy the conversion facility's needs. This element of Sorghasaurus© facilitates the determination of the most cost-effective method of supplying the conversion facility with alternative biomass feedstocks while accounting for any additional resources (i.e, labor, machinery, etc.) needed due to the differing conversion efficiencies.[45]

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[45] The conversion efficiency of different biomass feedstocks is an important issue that will impact the amount of acreage required to supply a conversion facility, the biomass feedstocks produced, and the production cost of alternative biomass feedstocks. Although considered to be a topic of substantial importance, information on the conversion efficiencies of alternative biomass feedstocks could not be identified for use in this research. Attempts were made to locate and obtain data on the conversion efficiencies of alternative biomass feedstocks but no published information was found. Discussions with Rooney (2010) and Blumenthal (2010) lead to the resolution that there is no known set of such conversion

Storage Adjacent to Conversion Facility

Included in Sorghasaurus© is a storage alternative that can be accessed on an as needed basis; that is, the amount of storage space is not restricted within the model, but rather determined endogenously within the model's optimization process. Periodic demands of the conversion facility are satisfied with a balance of "Just-In-Time" deliveries along with other deliveries which are stored until needed (table A4e).

It is assumed in Sorghasaurus© that all biomass feedstocks are placed in storage (e.g., even biomass feedstocks delivered "Just-In-Time") before being used by the conversion facility. This assumption is made because storage is located adjacent to the conversion facility and biomass feedstock delivered "Just-In-Time" will have to be placed somewhere (i.e., stored) before being used by the conversion facility. Thus, this storage mechanism captures the handling costs associated with received biomass feedstocks. The maximum amount of storage space required is a function of how much of the conversion facility's requirements must be stored long-term versus that received and simply passed through to the conversion facility "Just-In-Time."

All biomass feedstocks are assumed stored in a bunker-style silo; therefore, storage capacity is expressed in cubic feet. As biomass feedstocks move to storage, they are converted into a cubic foot per ton measurement based on physical density. For example, each silo bunker has a capacity of 245,760 cubic feet and one ton of HES at 75

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efficiencies to date, although they (i.e., Rooney and Blumenthal) support the thought that such efficiencies most probably vary across alternative biomass feedstock sources. The U.S DOE provides a Theoretical Yield Calculator, but maintains that actual yield could range from 60 to 90 percent of the theoretical yield (U.S. Department of Energy 2009c).

percent moisture is calculated to be 69.9 cubic feet per ton. Thus, 3,514.4 tons of 75 percent moisture HES can be stored in one silo bunker. Once stored, biomass feedstocks are transported to the conversion facility on an "as needed basis." Biomass feedstocks delivered to storage on a wet basis (e.g., HES) must be converted into a dry basis before being used to meet conversion facility requirements. As all biomass feedstocks move out of storage to the conversion facility, they are converted by the conversion facility,[46] into a dry basis (i.e., 15 percent moisture content). This assumed process allows for a biomass feedstock with a consistent moisture content to be delivered to the conversion facility.

Storage Transfers

A feature included in Sorghasaurus© allows all biomass feedstocks in storage to be transferred from period to period with a model-user-specified storage loss factor accounting for any degradation of the stored biomass feedstock. This allows HES biomass feedstock to be stockpiled when HES production and harvest is possible and used during later periods when there is no HES production. This feature also allows for SG, purchased delivered alternative biomass feedstocks, and purchase transported alternative biomass feedstocks to be stored and transferred from period to period if model application determines that to be the most economical strategy for the model-user-specified conditions. For example, if the only biomass feedstock available is purchased transported alternative biomass feedstocks and they are only available during the June A

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[46] The costs of such moisture conversion are assumed to be borne by the conversion facility and thus are not considered in the logistic costs reported in this thesis research.

period, application of Sorghasaurus© would purchase and transport enough of this biomass feedstock during the June A period to storage[47] to meet the conversion facility's biomass feedstock requirements for the entire year and thus transfer the stored biomass feedstock from period to period.

The amount of biomass feedstock carried over from period to period is dependant on: (1) tons of biomass feedstocks harvested or purchased during each period, (2) the cellulosic conversion facility's periodic requirements, (3) the capital investment and annual operating costs of storage facilities, and (4) the model-user-specified storage loss factor. As mentioned earlier, once biomass feedstocks are harvested, they are transported to storage where they remain until they are needed by the conversion facility. Some biomass feedstock might remain in storage for several months before being used, since HES is only harvested during certain periods and alternative biomass feedstock supplies might only be available during certain times of the year. Once the conversion facility's requirements are met by stored biomass feedstock during a certain period, any excess biomass feedstock in storage is degraded by a specified storage loss factor (e.g., one percent per period[48]) and transferred to the subsequent period for use or further storage.

[47] The model application would also account for the costs of acquiring and maintaining sufficient storage facilities to store a complete year's supply of biomass feedstock for the conversion facility.

[48] Throughout this thesis, a storage loss of one percent per period is mentioned. Readers are reminded this parameter is specified by the model user and can be any amount between 0 and 100 percent.

Cellulosic Conversion Plant's Bi-Weekly Biomass Feedstock Requirements

Application of Sorghasaurus© to a specified conversion facility size in a designated geographic region allows the model user to establish the amount of biomass feedstock required by the conversion facility during each of the 24 bi-weekly periods. Determining the least-cost sources, the type(s), and amounts of biomass feedstocks required by the conversion facility on a periodic basis is the essential objective of using Sorghasaurus©. Meeting this objective largely determines the outcomes (i.e., level of occurrences) of the other activities; that is, Sorghasaurus'© minimizing cost feature seeks to either harvest or purchase biomass feedstock sources in a least-cost economic portfolio method. Allowing the model user to specify conversion facility requirements within Sorghasaurus© facilitates holistic consideration of the logistics cost for any size conversion facility.

To facilitate incorporation of an additional risk management strategy designed to assure continual supplies of biomass feedstock being available throughout a conversion facility's year-round production cycle,[49] included in Sorghasaurus© is a feature allowing for model-user-designation of additional quantities (expressed in period equivalents) of biomass feedstock requirements being in storage. For example, in the baseline first-year application of Sorghasaurus©, an extra three periods of supply (i.e., 48,600 dry tons) of biomass feedstocks are required to be in storage beyond satisfying the year-round needs of the conversion facility. This is a one-time requirement to build slack biomass feedstock supplies (insurance) for assuring biomass feedstock demand will be satisfied.

[49] This risk management strategy is in addition to the previously-mentioned risk management strategy of establishing and maintaining buffer SG acreage beyond that required to supply the conversion facility with a year-round supply of biomass feedstocks when expected HES and SG yields are realized.

Transfer Tractor Hours

Since managing capital investments is important to minimizing costs, Sorghasaurus© includes a feature which facilitates selected tractor sizes and hours being used for several other field operations besides the initial-specified operations for each such tractor size (table A4f). For example, excess Tractor Size 1 hours may be transferred to field operations for which Tractor Size 2 is used. This allows excess/surplus hours of Tractor Size 1 capacity to be used to assist in performing these field operations and perhaps reduce the need for purchasing more Size 2 Tractors, since the Tractor Size 1 have already been acquired and may be sitting idle during these times.

Overhead Management and Support Staff

Overhead management and support staff labor resources are modeled in Sorghasaurus© since a corporate-style business model is assumed for the CBFFE (table A4f). The model user can specify the number of individuals in each corporate position. The number of field staff and logistics supervisors hired is determined as a function of full- and part-time labor hires. Therefore, the model user can specify how many full- and part-time laborers a single field staff and logistics supervisor can manage.

Resources and Constraints Levels

Table A4g contains a listing of what are commonly referred to as the RHS signs and constraint levels for all of the various resources and other constraints embedded in the Sorghasaurus© model. The signs follow the standard conventions of linear programming modeling. The "us" references are indicative of the several parameters that are "model-user-specified," allowing tailoring of the model's application to a specific region, problem, situation, etc. Details for the scope of these respective variables and the levels of the associated parameters used in the Middle Gulf Coast, Edna-Ganado, Texas area application of Sorghasaurus© are presented in Appendix D.

Integer Programming Features of Sorghasaurus©

Whole-number integer unit restrictions are imposed on all capital item purchases (i.e., for the headquarters, HES and SG land, purchased machinery, irrigation wells, re-lift pumps, and storage units) and also for full-time labor hires. The related activities in the linear programming model may enter the solution in whole-number increments or not at all; that is, no fractional solutions are allowed for these activities. Integer restrictions are used for these activities to reflect real-world conditions in which it is not appropriate to assume that a fraction of these items is ordinarily available for purchase. Sensitivity analyses related to this modeling assumption can be conducted, however.[50]

[50] Results for "turning off" the integer programming requirement in the baseline scenario are reported as part of the sensitivity scenarios section, scenarios 9D and 9E.

BASELINE RESULTS

This thesis research study is the inaugural application of Sorghasaurus©. The extensive discussion here in is intended to both (1) validate the scope and framework of the model and (2) provide extensive insights regarding the relative importance of specific individual parameter assumptions for the Middle Gulf Coast, Edna-Ganado, Texas area. A two-phase analytical process is followed in presenting model results: (1) a baseline scenario is defined and analyzed for which optimal production of both HES and SG biomass feedstocks occurs, providing a benchmark for subsequent comparison purposes; and (2) a series of sensitivity analyses are investigated, focusing on various logistical features and associated critical data. These sensitivity scenario analytical results are compared to those for the baseline scenario with consideration for (1) determining if the results obtained change in the anticipated direction (thereby validating Sorghasaurus©), and (2) identifying the magnitude of changes which signify relative importance (or lack thereof) of the respective factors or variables. As noted in Perry et al. (1986),

> "Because reality is complex and often not quantifiable [in an absolute sense], models are in fact representing a simplified version of reality. As such, the true value of analysis by modeling is 'to help develop insights into system behavior which in turn can be used to guide the development of effective plans and decisions' (Geoffrion 1976)."

Perry et al. (1986) proceed to note the value of identifying and understanding the "directional and/or magnitudal changes between two sets of results."

The cost estimates and capital requirements embedded in these analyses are derived from the previously-introduced methodology, the Sorghasaurus© model application, and the primary and secondary data provided for the baseline scenario analysis (refer to Appendix D). The results discussed in this section represent the Year 2 Baseline Scenario[51] analysis of HES and SG and are used as a benchmark for comparison to results for subsequent sensitivity scenarios. Due to many factors of uncertainty, there is no one, single-best solution, but rather a suite of solutions are presented to provide insight both on (1) cost per dry ton of biomass feedstock delivered to the conversion facility, and (2) those factors/parameters that have the greatest impact on this cost.

For the baseline scenario, a CBFFE approach is assumed for supplying a 30-million gallon conversion facility with all of its annual required biomass feedstocks[52]. Extended details regarding the specifics of the baseline data for the several components comprising Sorghasaurus© are presented in Appendix D. In this main text section of the thesis, the baseline scenario is summarized to provide an understanding of the paradigm in which the logistic economics of biofuels production are being evaluated in this research. This summary is the basis for establishing the framework of the several sensitivity scenarios which are evaluated to identify the relative importance of various factors in terms of their effects on bottomline costs of delivering biomass feedstocks to the conversion facility.

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[51] The focus on Year 2 (rather than Year 1) of the baseline scenario is subsequently explained.

[52] Although Sorghasaurus© is structured to allow purchasing of the biomass feedstock (e.g., woody materials, rice hulls), such supply options are not considered in this thesis research.

HES and SG are the only biomass feedstock sources considered as available to the conversion facility in the baseline analysis. It is assumed all biomass feedstocks are produced within a 30-mile radius of the conversion facility located between Edna and Ganado, Texas, near U.S. Highway 59, and that 15 percent of the land (i.e., 271,433 acres) within the area (i.e., a total of 1,809,555 acres) can be leased by the CBFFE without adversely affecting the land rental market, i.e., without resulting in an increase in land rental/leasing rates. Land planted for the production of HES and SG is cash leased at an effective annual rate of $57.50 and $22.50 per acre, respectively. Except for the custom farming of SG pre-harvest, all machinery and equipment resources used for production, harvesting, transportation, and storage of biomass feedstocks are purchased outright by the CBFFE, i.e., none are leased.

Availability of both full-time labor and part-time labor is assumed in the baseline scenario; however, the latter is assumed restricted to being able to perform a limited set of harvesting operations. Full-time laborers are allowed to perform any production, harvesting, transportation, or storage operations whereas part-time labor availability is capped at a specified number of hours available only during the HES harvest periods. This latter assumption is associated with part-time laborers only being allowed to drive the in-field buggies during HES harvest, in the event there is not ample full-time labor available. The assumption is that relatively-skilled labor is required for most of the year, with the amount thereof exceeding the local part-time labor supply, requiring full-time labor for the majority of the positions.

Irrigation is used in the baseline scenario as a risk management strategy to facilitate HES stand establishment and enhance yield to provide sufficient biomass feedstock being available to meet the conversion facility's periodic requirements throughout the year. HES is irrigated at a rate of 16.67 acre-inches per acre[53] (i.e., two split, early-season applications) and is the only biomass feedstock irrigated in the baseline scenario. HES is allowed to supply an unrestricted amount of biomass feedstock to the conversion facility (subject to Sorghasaurus'© optimization processes) whereas SG is restricted to supply a maximum of 25 percent of the total amount of biomass feedstock required by the conversion facility[54]. Thus, SG is allowed to supply up to 100,000 dry tons or 25 percent of the total requirement. In the baseline scenario, 400,000 dry tons of biomass feedstock are required annually by the conversion facility. Cost per gallon of biofuel was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Two risk management strategies are incorporated into Sorghasauras© to provide insurance against sub-par crop yields or years of no production (e.g., extreme drought, hurricane immediately prior to or during harvest). The first strategy is that an extra three periods' supply of biomass feedstock will be produced during the first year of operation and kept in storage to be used during times when biomass feedstocks may not be

[53] HES is flood irrigated with 16.67 inches (i.e., two 8.3 acre-inch flood applications) of water per acre during the early weeks of the growing season to assure stand establishment and reduce yield variability (Blumenthal 2010). It is assumed that 40 percent of the irrigation water pumped (i.e., 6.67 of the total 16.67 acre-inches applied per acre) will be "lost" as a result of using an open-canal delivery system and furrow irrigation (Raun 2010; Falconer 2010). Thus, two five acre-inch effective applications are ultimately applied per acre.

[54] This assumption is associated with the focus of this research being on the economic competitiveness (or lack thereof) of HES, and its capability of being a viable source of biomass feedstocks in the targeted study area.

delivered "Just-In-Time" and other inventory supplies are limited or non-existent. The second strategy is that besides any SG acreage identified by Sorghasaurus© as being part of the base portfolio (along with HES) to supply the conversion facility's annual requisite 400,000 dry tons of biomass feedstocks, additional SG acreage will be established to supply, if need be, 25 percent of the total amount of biomass feedstock annually required by the conversion facility. This insurance SG acreage will not be harvested, however, unless it is needed by the conversion facility in the event of shortfalls in HES production due to excessive drought, harvest-time climate events (e.g., hurricanes), or other catastrophic events. If the insurance SG acreage is not harvested, the baseline scenario assumption is that it will be leased out for grazing at a rate of $5 per acre[55]. Both risk management strategies are included in the Year 1 baseline scenario, whereas, only the second risk management strategy (i.e., SG land grown for insurance) is considered for the Year 2 Baseline Scenario (which is the scenario used for comparison to all of the sensitivity scenarios). That is, accumulation of an extra three periods of biomass feedstock supplies is a one-time event at the beginning of the conversion facility's operation[56].

It is assumed that there is often steady-state biomass feedstock production and delivery which facilitates maintenance of reserve biomass feedstock supplies. Consequently, results of the Year 2 Baseline Scenario (as opposed to Year 1) are used as the basis of comparison in the subsequent sensitivity scenarios.

[55] In the results presented in this thesis, it is always assumed the insurance SG acreage is not harvested.

[56] In all likelihood, this insurance cushion of stored biomass feedstock supplies would be accumulated during the first to three years of operation, depending on harvested yields. It is identified here as occurring in year one to focus explicit attention on the costs associated with this issue.

This section is organized as follows:

- Total Costs;
- Capital Investment Costs;
- Variable Operating Costs;
- Timing of HES Field Operations; and
- Harvest, Transportation, and Storage.

Overview of High-Energy Sorghum and Switchgrass Results

Relying on the assumptions embedded in the designated baseline scenario, the total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks is $53.60 million, i.e., $723.67 per harvested acre, $1.7867 per gallon of fuel produced, and $134.01 per dry ton of the requisite 400,000 tons of biomass feedstock (table A5).

A total of 313,266 dry tons of HES is produced on 36,845 acres and a total of 100,000 dry tons of SG is produced on 37,225 acres to jointly meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,266 dry tons on 74,070 acres. Although only 400,000 dry tons are required by the conversion facility annually, excess production is required due to bi-weekly periodic storage losses being set at one percent per period. To incorporate the risk management strategy, an extra 40,000 acres of “insurance” SG is planted and established, but not harvested; $5 per acre pasture rent receipts are credited for this acreage. Accounting for the two acres of HES rotation acreage per planted HES acre, the total farm acres are 187,760 (i.e., 36,845 + (2x36,845) + 40,000)

The average harvested HES and SG yields equate to 8.50 dry tons per acre and 2.69 dry tons per acre, respectively. Although a maximum HES yield of 12 dry tons per acre and 3 dry tons of SG per acre are considered possible (Rooney 2010; Blumenthal 2010), these maximum yields are not achieved on average due to different planting/harvest dates occurring (to realize capital machinery cost economies). Dividing the total annual cost by the total acres and the total tons produced results in an annual per acre cost of $723.67 and a per dry ton delivered and stored biomass feedstock cost of $134.01[57]. Assuming a fuel conversion rate of 75 gallons per dry ton (Avant 2009) and a 30-million gallon conversion facility size, total-delivered biomass feedstock costs are $1.7867 per gallon of fuel produced[58]. The annual cost components as a percent of the total cost are presented in table A5 and figure A3. In table A5, the rows for those components representing more than or equal to 10 percent of the total costs arbitrarily are bolded, signifying their greater degree of magnitude. There are four cost components in this arbitrary classification: Purchased Machinery, Full-Time Labor, Irrigation, and HES Field Operations.

[57] In this thesis research, it is assumed that a dry ton of HES is equivalent to a dry ton of SG for biomass conversion purposes. As noted elsewhere, a “dry” ton is assumed to be at 15 percent moisture (Rooney 2010; Blumenthal 2010).

[58] Cost per gallon of fuel was determined by dividing total annual cost by 30 million gallons, since a 30-million gallon/year conversion facility is assumed.

Results by Major Cost Category

In this section, the aggregate results for the benchmark Year 2 Baseline Scenario noted previously are separated into capital investment and operating costs. This presentation format is used to provide a greater understanding of the individual segments that significantly contribute to the cost of delivering HES and SG biomass feedstocks to the conversion facility under the baseline assumptions.

Annual operating costs comprise $38.7 million (72.17 percent) of the total annual cost while capital investment costs (calculated on an annuity equivalent basis – ownership costs (including insurance, property taxes, and fixed repairs)) make up the remaining $14.9 million (27.83 percent) (table A6 and figure A4). There are various significant items that contribute to each of these costs; these items are discussed in the following section. Capital investment costs are presented first and then a discussion of the operating costs follows.

<u>Capital Investment Costs</u>

Capital investments and associated ownership costs are summarized in table A7 and figure A5 and presented in detail in table A8. The total requisite initial investment for the CBFFE is estimated to be $118.3 million while the annual ownership costs (including insurance, property taxes, and fixed repairs) expressed on an annual basis are estimated to be $14.9 million (calculated on an annuity equivalent basis). Purchasing machinery is the most significant cost associated with capital investments, accounting for 56 percent of the total $118.3 million (table A7).

A total of 541 pieces of machinery and equipment are purchased, counting semi trucks and semi trailers as separate units. There are seven major capital investment categories (i.e., arbitrarily defined as such based on their accounting for greater than five percent of total capital investment costs) that have a substantial impact on total capital investment costs; the rows for these major items are bolded in table A8. These capital item categories include purchasing (1) transport trucks (13.22 percent), (2) irrigation wells (11.15 percent), (3) storage (9.72 percent), (4) HES harvesters (7.94 percent), (5) custom establishment of SG land for insurance (5.88 percent), (6) custom establishment of SG land for production (5.48 percent), and (7) tractor size 2 (5.35 percent). These seven categories of capital investments, in aggregate, account for 58.74 percent of total capital investment costs.

Altogether, capital costs comprise 27.83 percent of the total annual cost to supply a 30-million gallon cellulosic conversion facility with biomass feedstocks. These costs translate into \$201.42 of the total \$723.67 per acre costs, \$37.30 of the total \$134.01 per dry ton of biomass feedstock costs, and \$0.4973 of the total \$1.7867 cost per gallon of fuel (tables A7 and A8).

Semi Trucks

Purchasing semi trucks for field-to-storage biomass feedstock transport is the most significant annual capital investment cost, accounting for nearly \$2.00 million (13.22 percent) of the total capital costs on an annual basis (table A8). This cost is solely for the semi truck units, exclusive of the semi trailers. This somewhat relatively-large, unexpected result (i.e., the substantial large proportion cost of this category of equipment) is due to the short total time span in which the semi trucks are mostly used (mainly during the July A to November B HES harvest season) and the amount of HES tonnage that must be hauled real-time[59] (as HES is transported on a wet basis). That is, if the possibility of short-term leasing or custom hiring of transport trucks is ignored/disallowed, numerous semi truck end-dump trailer units must be purchased to transport HES during the nine-allowed bi-weekly harvest periods. Since SG is allowed to be harvested over the entire year (i.e., 24 time periods), the use of the semi truck flatbed semi trailer units for SG transportation is allowed to be spread out over more periods, significantly reducing the required purchases when SG is considered as an unconstrained part of the biomass feedstock supply chain for the conversion facility[60]. Another possibility worthy of further study is the use of intermediate storage/processing centers located near the production fields, as described by Larson et al. (2010). An important topic of such investigations are the related rates of biomass feedstock deterioration at different locations.

Irrigation Wells

Developing new irrigation wells is the second-most substantial annual capital investment cost, accounting for almost $1.70 million (11.15 percent) of total capital cost on an annual basis (table A8). This high cost is due to the substantial number of acres of HES

[59] The logistics of the harvesting operation requires that the harvested biomass feedstocks be transported immediately to the conversion facility storage site inasmuch as no intermediate storage possibilities are assumed in this research.
[60] This issue is evaluated in subsequent sensitivity scenario analyses.

that must be irrigated, the amount of water that is applied to the fields, and the assumed pumping capacity of the wells. If seasonal rainfall is assumed more prevalent than that represented in figures D1 and D2 of Appendix D, the amount of irrigation water assumed to be required could be reduced, resulting in a lower number of irrigation wells being purchased and a lower per acre/per-harvested ton cost.

Storage

Purchasing storage units comprises $1.45 million (9.72 percent) of total annual capital costs (table A8). Such relatively-high proportional costs are attributed to the relatively-narrow harvest window for HES biomass feedstock (i.e., July A through November B) and the related large amount of biomass feedstock that must be harvested and stored during these periods to supply the conversion facility year-round. As biomass feedstocks are harvested, they are transported to the conversion facility where they are either used immediately, or stored until a subsequent period, to meet the conversion facility's biomass feedstock requirements. As biomass feedstocks move out of storage to the conversion facility, storage space is opened up and subsequent additional harvested biomass feedstocks are allowed to be stored in that space, thus minimizing the amount of storage units that must be purchased. A total of 148 storage units (each capable of handling 245,760 cu/ft of biomass feedstock) are required to store the 950,719 wet tons of HES and the 100,000 dry tons of SG.

Harvesters

Acquiring harvesters is the third-largest capital cost, accounting for nearly $1.18 million (7.94 percent) of total capital investment costs on an annual basis (table A8). Although only 13 harvesters are required, the annual payment for one harvester (which has a purchase price of $369,613) is the largest of any other capital item, accounting for $91,129 annually. The magnitude of this payment is due to the harvesters' high rate of annual use and the relative-short expected useful life, i.e., 850 hours per year and 4 years, respectively. If the possibility of short-term leasing on an economical basis at less than the cost of annual ownership exist, the annual cost of these harvesters could perhaps be reduced. Similarly, if HES harvest moisture could be lowered, per hour dry ton harvesting capacity could be increased, reducing the required number of harvesters.

SG Custom Establishment for Production and Insurance

Custom establishment of SG land grown for insurance and SG production account for $878 thousand (5.88 percent of total capital investment costs) and $817 thousand (5.48 percent of total capital investment costs) of annual investment costs, respectively (table A8). Establishment of SG land grown for insurance and production is such a significant cost due to the large amount of acreage (i.e., 37,225 acres) on which SG must be established to annually produce 100,000 dry tons, since the average annual harvested SG yield is assumed to be only 2.69 dry tons per acre in association with a maximum-expected yield of 3.0 dry tons per acre (Epplin 2009; Blade Energy Crops 2009). If higher SG yields could be realized, the land base for SG could be reduced, thus reducing the cost of custom establishment.

Tractors

Obtaining Tractor Size 1 (225hp) and Tractor Size 2 (152hp) accounts for $694 thousand (4.65 percent) and $798 thousand (5.35 percent) of annual investment costs, respectively (table A8). Although steps were taken to reduce the required numbers of these items (i.e., Tractor Size 1 hours are allowed to transfer to HES activities requiring Tractor Size 2 and Tractor Size 1 and 2 hours are allowed to transfer to SG activities requiring Tractor Size 3), these two items still account for a significant portion of capital costs. This substantial set of costs is due in part to the large annual costs for each of these items and the extensive use of these tractors in almost every field operation for HES and SG production combined with the consideration of the probability of trafficable days in this research. In particular, a large number of tractors are required during harvest, especially for pulling buggies during HES harvest. As is the case for semi truck-trailer units and harvesters, if short-term leasing is allowed at an economical rate, the costs of tractor sizes one and two could perhaps potentially be reduced.

Annual Operating Costs

Annual operating costs are presented in summary form in table A9 and figure A6 and in detail in table A10. Total annual operating costs are estimated to be $38.68 million and contribute $522.25 to the total $723.67 per harvested acre costs, $96.71 to the total

$134.01 per dry ton biomass feedstock costs, and $1.2894 to the total $1.7867 per gallon of fuel costs, i.e., 72.17 percent of total costs (figure A4). Annual operating costs are comprised of various costs relating to the acquisition and use of land, labor, irrigation, HES field operations, SG field operations, transportation, transfer tractor hours, and overhead management. Labor (22.91 percent) and HES field operations (30.35 percent) are the most substantial costs, accounting for 53.26 percent of total annual operating costs (table A9).

There are seven major operating cost categories (i.e., arbitrarily defined as such based on their accounting for greater than five percent of total annual operating costs) that substantially contribute to variable operating costs; the rows for these major items are bolded in table A10. These categories include (1) HES field operations (mainly fertilizer) (30.35 percent), (2) full-time labor (21.50 percent), (3) overhead management (10.02 percent), (4) irrigation (8.89 percent), (5) transport HES (8.83 percent), (6) SG field operations (8.78 percent), and (7) HES land (5.48 percent). Together, these seven operating cost categories comprise $35.14 million (93.2 percent) of the total annual operating costs.

HES Field Operations

The single-largest category of annual operating expense is associated with performing HES field operations. The specific costs for these operations include fuel, repair and maintenance, and the cost of any inputs required (i.e., fertilizer, seed, etc.). Combined, these operations contribute 30.35 percent of total variable operating costs (table A10).

Of this 30.35 percent, 18.06 percent of the costs are attributed to fertilizing, 3.80 percent of the costs are for planting, 5.12 percent of the costs are for harvesting, and the remaining field-operating costs constitute 3.37 percent of the total annual variable operating costs. Fertilizing is such a substantial portion of the operating costs due to the large amount of fertilizer nutrients (240 lbs of nitrogen - 80 lbs of phosphorus - 160 lbs of potassium applied per acre) required on each of the 36,845 HES acres. A total of 8.84 million pounds of nitrogen, 2.95 million pounds of phosphorus, and 5.90 million pound of potassium are required annually on the HES acreage, summing to $6.28 million.

Harvesting includes the costs of operating the harvester, the tractors, and the in-field buggies. A major factor contributing to the harvesting costs is the amount of wet tonnage that must be hauled, as this factor impacts the number of acres hauled per hour capacity by the in-field buggies. That is, as the moisture content of the biomass feedstock increases, the more time it takes to haul the biomass feedstock being harvested from one acre to the transport semi trucks and semi trailers, thus increasing the cost per acre of the in-field buggies. The cost of operating the harvester alone accounts for $962 thousand, while the remaining $1.02 million is attributed to the in–field buggies[61]. If weather conditions permitted omitting the in-field buggies and loading straight from the harvester into the semi trailers, the cost of the harvesting operation could potentially be reduced. However, this scenario is highly unlikely in the Middle Gulf Coast, Edna-

[61] The costs associated with the in-field buggies include fuel and lubrication for tractors and repair and maintenance for the tractors and buggies. Labor costs are accounted for separately.

Ganado, Texas area due to the clay-type of soil in the area and typical harvest-time climate conditions (Raun 2010; Popp 2010).

Although planting does not account for greater than five percent of operating costs, it is still important to consider the cost of this operation as it comprises a substantial portion of farm gate cost, i.e., ignoring transportation and storage costs. The main cost associated with the planting operation is purchasing HES seed. To realize a planting rate of seven pounds per acre on 36,845 acres, 257,915 pounds of HES seed are required at a cost of $5/lb (Rooney 2010), totaling $1.29 million annually.

Full-Time Labor

The second-largest variable operating expense is hiring full-time labor, which constitutes 21.50 percent of total variable operating costs, totaling $8.32 million per year (table A10). Allowing only full-time labor to perform the majority of farming operations is a major limitation imposed on the benchmark baseline scenario inasmuch as a majority of the 170 employees are not needed to perform field, transportation, or storage operations during the bi-weekly periods December A through July A periods (figure B7). The only periods where all full-time employees are utilized are the July B through November B periods, corresponding to harvest, transportation, and storage of HES.

A total of 10,000 hours of part-time labor (approximately 39 laborers) is considered available, but not necessarily hired (the model decodes that amount) during each period[62] in the baseline scenario to drive the in-field buggies in the harvesting operation. Allowing part-time labor to drive the in-field buggies instead of hiring full-time employees results in a cost saving of approximately $1.36 million.[63]

The three most labor-intensive field operations are harvest, transportation, and storage. Depending on trafficable days available and wet ton harvested yield levels, harvest requires between 30 and 58 laborers, per bi-weekly period transportation requires between 49 and 115 laborers per bi-weekly period, and storage handling uses between 12 and 34 laborers per bi-weekly period for the periods July A through November B (figure 8).[64]

Overhead Management

The cost to hire an overhead management team accounts for 10.02 percent, totaling $3.88 million of annual operating costs (table A10). Overhead management is seen as a critical part of this farming operation due to the extensive acreage farmed and the planning required to successfully supply a conversion facility with a continuos, year-round supply of biomass feedstock. These management fee costs are synonymous with residual returns

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[62]Within Sorghasaurus©, an hour of part-time labor is assumed equivalent to an hour of full-time labor in terms of productivity. In terms of hours worked per period, equivalent hours are assured for both full- and part-time labor. However, a block of full-time labor hours is acquired in discrete, whole-number integer units per each employee whereas part-time labor is acquired on a continuous basis in one-hour increments.
[63] Cost savings of $1,363,712 are calculated by subtracting the cost of 39 part-time employees (i.e., $544,461) from what the costs would have been if they were hired as full-time employees (i.e., $1,908,173).
[64] There is considerable variation in the number of laborers required during each of these periods because the number of laborers needed is dependant on the number of acres worked each period for harvesting and the related amount of biomass feedstock harvested each period which impacts labor requirements for transportation and storage handling.

to management and labor occurring in sole proprietorship businesses; however, in this research study, the costs are explicitly included as opposed to being a residual factor.

Irrigation

Pumping groundwater for irrigation comprises 8.89 percent, totaling $3.44 million, of annual operating costs (table A10). The relative-large amount of this cost is mostly due to the assumption that 16.67 acre-inches of water are applied per acre of HES (Blumenthal 2010; Falconer 2010; Raun 2010). Thus, a total of 614,206 acre-inches of water must be pumped to realize an applied rate of 16.67 acre-inches across the 36,845 acres of HES. The annual operating costs for irrigation include fuel, repair, and maintenance for the irrigation pumps and re-lift pumps and the cost to purchase poly-pipe for water delivery. A total of 627,880 feet of poly-pipe is required to irrigate 36,845 acres of HES, totaling $102 thousand. Because of the field-rotation nature of HES production and the perceived prohibitive transaction costs of retrieving and storing the used poly-pipe between seasons, a one-year useful life is assumed for the poly-pipe, i.e., this is a recurring annual cost.

SG Field Operations

Growing and harvesting SG accounts for $3.40 million (8.78 percent) of annual operating costs (table A10). Since all SG establishment operations are conducted by custom operators, these “growing and harvesting SG” costs only include spraying herbicide ($202 thousand), fertilizing ($1.95 million), cutting ($204 thousand), raking ($42 thousand), baling ($320 thousand), and transporting and stacking ($606 thousand). The field operation that contributes most substantially to the cost of the growing and harvesting SG is fertilizing. The magnitude of this cost is largely due to the extensive amount of fertilizer nutrients (60 lbs nitrogen - 20 lbs of potassium - 40 lbs of phosphorous applied per acre) required on 37,225 SG acres[65]. Fertilizing SG acreage requires 2.23 million pounds of nitrogen, 745 thousand pounds of phosphorus, and 1.50 million pounds potassium annually, summing to $1.74 million.

HES Transportation and Storage

Transporting and storing HES at the conversion facility accounts for $2.26 million (8.83 percent) of total variable operating costs (table A10). Transporting the HES from the field to the storage facility accounts for $1.45 million of the total costs while storing accounts for the remaining $807 thousand. These costs include fuel and lubrication for the semi trucks and storage-handling equipment and repair and maintenance for the semi trucks, semi trailers, and storage equipment. The main factor contributing to these costs is the amount of wet tonnage that must be hauled, as HES is transported on a wet basis. A total of 950,719 wet tons of HES must be transported to the conversion facility, although only 313,266 dry tons are utilized by the conversion facility[66]. Thus, a total of

[65] Similar to HES, the assumption is 20 pounds of nitrogen per expected harvested ton of SG biomass feedstock and a complete applied ratio of 3-1-2 for N-P-K (Blumenthal 2010).

[66] A dry ton has a moisture content of 15 percent; the moisture range for harvested HES is 60-75 percent. (Blumenthal 2010; Rooney 2010). Use of the classic minary shrink formula {wet weight x ([1-wet moisture percent] / [1 - dry moisture percent])} allows for calculating the number of dry tons of HES. Using an average harvested moisture content of 61.348 percent, the 950,719 wet tons harvested are equivalent to 313,266 dry tons. Excess water is calculated by subtracting the total dry tons harvested from the total wet tons produced (950,719 wet tons - 313,266 dry tons = 637,453 tons of water). Then, dividing 637,453 tons of water by 2,000 pounds equals 1,274,905,835 pounds of excess water. Dividing

489 acre-feet of excess water is hauled by the trucks annually to the conversion facility. The possibility of reducing the moisture content of the HES either by crimping the biomass feedstocks prior to loading in the end-dump semi trailer or air drying in the field could potentially reduce the amount of water that must be hauled and disposed of by the conversion facility, thereby reducing these transportation costs.[67, 68]

HES Land Rental

Cash leasing HES land constitutes 5.48 percent of total variable operating costs, totaling $2.12 million annually (table A10). This cost is associated with the premium cash lease rate (i.e., $57.50 per planted acre) that must be paid for land to encourage landowners to change their land in use from current production into HES. Another factor contributing to this cost is that a three-year rotation is used and it is assumed all land must be continually rented from the landowner, including rotation acreage on which HES is not being produced in the current year. Therefore, $2.12 million represents the total cost each year for planting and producing HES on 36,845 acres, since a total of 110,535 acres are leased.[69]

that value by the weight of a gallon of water, 8.33 pounds, equals 153,049,920 gallons of excess water. Next, dividing that amount by 325,851 gallons of water per acre-foot is equivalent to 469.69 acre-feet of excess water.

[67] Refer to Larson et al. (2010) for a discussion of the value of intermediate processing of biomass feedstocks. A sensitivity scenario is used in this thesis research to further investigate this issue.

[68] These latter water disposal costs are not considered in this thesis' analyses.

[69] Since a three -year rotation is used (i.e., one year in HES and two years out), a total of 110,535 acres (36,845 X 3= 110,535) must be leased every year so the fields can be rotated in the appropriate manner to sustain their agronomic proficiency (Blumenthal 2010).

Comprehensive Logistics Cost Perspective

Biomass feedstock logistics encompass all of the operations required to grow, harvest, transport, and store the biomass feedstock to guarantee the delivered biomass feedstock meets the specifications of the conversion facility (Energy Efficiency and Renewable Energy 2008). It is estimated that these costs comprise 35 to 65 percent of the total production costs of cellulosic biofuels (Fales, Hess, and Wilhelm 2007). The relative impact of each logistical segment is discussed in this section.[70]

For the Year 2 Baseline Scenario, production costs for HES and SG were the most significant costs, accounting for $29.68 million (55.38 percent) of total logistics costs (table A11; figure B9). Biomass feedstock production includes the costs to (1) purchase all required capital items, and (2) perform all field operations, including planting, irrigation, leasing land, and hiring labor. HES production accounts for $24.00 million (80.86 percent) of these costs while SG production comprises $5.68 million (19.14 percent). Producing HES accounts for a greater portion of production costs (relative to SG production) due to (1) it comprising 75 percent of the annual supply of the conversion facility's requirements and (2) the greater number of field operations that are required and the substantial fertilizer and irrigation requirements.

Harvesting HES and SG comprises $8.78 million (16.37 percent) of total annual logistics costs (table A11). Harvesting HES accounts for $6.94 million (79.08 percent) of these harvest costs while harvesting SG comprises $1.84 million (20.92 percent).

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[70] The costs of borrowing operating money, overhead management, and the headquarters are distributed across the logistics cost segments based on each segment's proportion of total annual costs.

Harvesting HES is very labor and capital intensive because of the narrow harvest window and the fact that HES is harvested wet, i.e., these factors combined greatly increases the number of laborers that must be hired and the number of harvesters and in-field buggies that must be purchased. Since SG can be harvested year-round on a “Just-In-Time” basis, it is possible to spread the capital purchases and labor hires over more periods and minimize the number (and costs) required.

Transportation for both HES and SG comprises \$8.31 million (15.50 percent) of the total \$53.60 million of all annual costs (table A11). Transportation costs include the costs to purchase semi trucks and semi trailers for both HES and SG, fuel, repair and maintenance, and labor. Transporting HES constitutes \$7.17 million (86.32 percent) annually while transporting SG comprises \$1.14 million (13.68 percent) of annual transportation costs. Similar to HES harvest, transporting HES comprises such a substantial portion of the costs due to the narrow harvest window and subsequent narrow transportation window and the amount of tonnage that must be transported during these limited time periods. HES requires 115 semi trucks and end-dump semi trailers while SG uses 20 of these same trucks and 20 flatbed semi trailers[71].

Storage comprises \$5.06 million (9.45 percent) of the total annual biomass feedstock supply costs (table A11). Storing HES accounts for \$4.47 million (88.29 percent) while SG accounts for the remaining \$593 thousand (11.71 percent) of total annual storage costs. The cost of storage includes the costs associated with purchasing the storage bunkers, land, hiring labor, and the purchase and operating costs of the

[71] The model facilitates shared use of the semi trucks among HES and SG transport activities.

storage-handling equipment. Purchasing the storage bunkers accounts for the majority of the storage costs due to the number required to store the amount of wet biomass feedstock harvested in a relative short period of time and the phenomena of the 25 percent maximum restriction imposed on using SG as a biomass feedstock.

Producing SG biomass feedstock insurance constitutes $1.77 million (3.30 percent) of the total annual logistics costs (table A11). This $1.77 million includes the costs of leasing the land and the cost to have a custom operator establish the SG insurance acreage. Since the SG insurance acreage is not fertilized, treated with herbicides, harvested, transported, or stored in the baseline scenario, there are no operating costs associated with its production.[72]

Field Operations Working Periods

The time periods during which the baseline scenario HES field operations occur are indicated in table A12. As mentioned previously, flows of land through and across time periods were modeled so that land could not have the same field operation performed twice nor flow backwards into previous field operations. This restriction helps maintain an orderly flow of land from the first HES field operation to the last HES field operation.

Two field operations can be performed during the same time period as long as there are enough trafficable days and machinery, equipment, and labor resources for both operations to be performed. For example, during the September A period, the second

[72] As noted elsewhere, the SG insurance acreage is incorporated into a five-year rotation with the SG production acreage such that four years out of five, all SG acreage is fertilized, treated with herbicides, and harvested.

discing and landplaning is performed on 2,208 acres. This simply means that the second discing and landplaning operations happened on the same acreage during the same time period, but not concurrently. For most field operations, the amount of acreage worked during each period is distributed through the allowed periods to minimize capital investments while simultaneously accounting for the harvested yield impacts of alternative timing of planting and harvest activities. That is, an explicit feature incorporated into the model structure of Sorghasaurus© is the important commitment to minimizing total cost of supplying biomass feedstocks to the conversion facility when recognizing economies on capital investments and accounting for prudent tradeoffs in field yields occurring across time periods, some of which may be at less than maximum yield levels.

HES and SG Transportation and Storage

The amounts of HES and SG biomass feedstocks that are carried over in storage from period to period to meet annual conversion facility biomass feedstock requirements on a bi-weekly basis in the baseline scenario are presented in table A13. Not included in table A13 is recognition nor accounting for the extra three periods of "insurance" biomass feedstocks inventory that were produced during year one of the baseline scenario. HES is only harvested during the July through November periods while SG can be harvested anytime throughout the year[73] and used as a supplemental source of biomass feedstocks for the conversion facility.

As biomass feedstocks are harvested, they are transported to the conversion facility where they are either used immediately (in combination with biomass feedstocks that are already stored), or stored until a subsequent period, to meet the conversion facility's biomass feedstock requirements. That is, any harvested biomass feedstock delivered in a specific period remaining after the conversion facility's periodic needs are met for that period, is left in storage and allowed to be used in subsequent time periods.

For example (table A14), during the July A period, 3,873 dry tons of biomass feedstock were not needed by the conversion facility to meet current biomass feedstock requirements; therefore, these unused biomass feedstocks were transferred to the July B period for subsequent use. Biomass feedstocks that are transferred from one period to the next incur a model-user-specified one percent loss; thus, by multiplying the biomass feedstock remaining after the July A period by 99 percent, only 3,384.27 dry tons of biomass feedstock are effectively transferred to the July B period. During the July B period, a total of 56,583 dry tons of HES are harvested and the cellulosic conversion facility requires 17,522 dry tons of biomass feedstock to operate during this period. After accounting for storage carryover from the previous period, 42,895 dry tons of biomass feedstock remain in storage at the end of the July B period for transfer into the August A period, less the one percent storage loss. Since the first HES biomass feedstock is

[73] Discussion during later stages of this thesis research suggests this is probably not the case and a sensitivity scenario was considered in which no SG harvest could occur during either April or May.

harvested during the Jul A period, this period essentially represents the beginning of the conversion facility's operating year and the Jun B period represents the end of the conversion facility's operating year. This is the reason that all of the biomass feedstock that has been transferred from period to period has been used by the Jun B period (table A13). That is, all biomass feedstock harvested during the year is used by the conversion facility and none remains in storage for the subsequent year's use excepting the designated three periods of insurance stocks.

Summary of Baseline Year 2 Results

A summary of the results for the Year 2 Baseline Scenario analysis are assimilated and reported in this section, providing the basis for comparison in the subsequent sensitivity scenario analyses. Table A15 is an itemized listing of what are considered to be the most critical barometers of performance for the specified hypothetical Middle Gulf Coast, Edna-Ganado, Texas biomass feedstock production area. Four sets of results are noted in table A15:

- Production Levels;
- Total Capital Investment and Operating Costs;
- Capital Investment Costs; and
- Annual Operating Costs.

For brevity purposes, attention is directed to two of the results:

- A $134.01 cost per dry ton of biomass feedstock produced; and
- A $1.7867 cost (biomass feedstock only) per gallon of biofuel.

Table A16 is a composite enterprise budget for the baseline scenario optimal solution prepared in an expanded format of that used by the Texas AgriLife Extension Service (2010) in exhibit C3. The notable enhancements to the budget format are the inclusion of columns for the proportional (i.e., percentage) contribution of each cost item as well as associated costs per harvested dry ton of biomass feedstock and total annual costs for the CBFFE. Inasmuch as both HES and SG production are included in the optimal solution for the baseline scenario, this budget is directed toward identifying the comprehensive costs for a weighted HES/SG dry ton of harvested biomass feedstock. Consequently, selected individual cost factors are reported for weighted amounts of HES (49.74 percent) and SG (50.26 percent) acreage comprising one average acre of harvested biomass production. To provide a more usual form of such an enterprise budget, tables A17 and A18 pertaining to the HES and SG monoculture sensitivity scenarios 4A and 4B, respectively, are presented here for comparison purposes.[74]

In table A16, a pseudo-standard enterprise budget format similar to that illustrated in exhibit C3 is presented for the Year 2 Baseline Scenario result of $134.02 per dry ton. As noted above, this is a weighted biomass budget, with 300,000 dry tons of HES[75] and 100,000 tons of SG represented, translated into an overall 5.4 dry ton biomass yield per acre (i.e., 4.05 tons HES on 0.4974 acres and 1.35 tons SG on 0.5026 acres).

[74] Results for these sensitivity scenarios are discussed in detail in the Sensitivity Scenario section. The "out-of-order" presentation of these budgets here is intended to facilitate comparison of the three alternative budgets and thereby enhance readers' ability to understand the relative results.
[75] Actually, 313,266 tons of HES are included to account for the storage loss incurred. However, for calculating the per ton costs, only the 300,000 tons of HES biomass used by the conversion facility are considered.

Land leasing is treated as a direct expense in this budget (although some may view it as a fixed expense due to the long-term, extended duration of the postulated land tenure contract between the CBFFE and landowners). Such delineation of this item of expense is consistent with its treatment elsewhere in this thesis, based on the fixed expense label only accorded to purchased/owned capital asset items.

Direct (variable) expenses are $469.94 per acre, $34.81 million for the total CBFFE operation, and $87.02 per dry ton, accounting for 64.94 percent of the total Year 2 Baseline Scenario costs. As discussed previously and also elaborated on in Appendix D, fertilizer and full-time labor costs are a substantial component of these expenses.

Fixed costs are comprised of the classic DIRTI 5–depreciation, interest, repairs, (property) taxes, and insurance associated with capital asset ownership (Lessley, Johnson, and Hanson 1991) and the amortization of custom establishment of SG acreage. These fixed expenses combined are $201.42 per acre, $14.92 million for the total CBFFE operation, and $37.30 per dry ton, accounting for 27.83 percent of the total Year 2 Baseline Scenario costs. The remaining 7.23 percent of costs are associated with management charges at $52.34 per acre, $3.88 million for the total CBFFE operator, and $9.69 per dry ton.

Table A17 is a similar presentation of the HES monoculture assumed in sensitivity scenario 4A in which the cost per dry ton totals $159.18. The cost breakdown is similar to that of the Year 2 Baseline Scenario – Direct Expenses are 65.11 percent of the total, Fixed Expenses are 27.73 percent, and Management Charges are 7.17 percent.

Enterprise budget results for the $88.22 per ton SG monoculture represented in sensitivity scenario 4B are presented in table A18. The results are similar to those realized in the Year 2 Baseline Scenario - 67.12 percent Direct Expenses, 23.96 percent Fixed Expenses, and 8.92 percent management charges.

SENSITIVITY SCENARIO ANALYSES

In this section, several sensitivity scenarios are considered, allowing for the identification of the magnitude of changes which signify the relative importance (or lack thereof) of the respective factors or variables. These sensitivity scenarios address many of the assumptions embedded in the Year 2 Baseline Scenario analysis, allowing for comparison of the results and determination of apparent significant factors that impact the cost to supply a 30-million gallon conversion facility with biomass feedstocks.

The major categories for which the impacts of modifying the assumptions investigated in these sensitivity scenario analyses are as follows:

1. Production for Insurance;
2. HES Yields;
3. SG Yields;
4. Monoculture;
5. Costs;
6. Machinery;
7. Moderate Aggregate Advances;
8. Substantial Aggregate Advances; and
9. Miscellaneous.[76]

The following spectrum of individual sensitivity scenarios for each of these categories are considered to evaluate the impacts of changes in one or more factors

[76] Five additional sensitivity scenarios regarding several assorted topics were investigated following a pre-thesis defense seminar and after the defense. Rather than rearrange the pseudo-final materials in the other categories, the results for these five scenarios were assembled in this “Miscellaneous” category.

considered important in affecting the costs ($/dry ton) of delivering biomass feedstock to a biomass conversion facility.

Scenario-specific categorical summary tables and related figures are discussed here to provide a general overview of the results and to accentuate those factors appearing to impact delivered biomass feedstock and related biofuel costs to the greatest degree, among those considered in this research. Summary tables based on table A15 are used in Appendix E for comparison purposes, with discussion limited to reporting the most apparent differences occurring in the results for the sensitivity scenario relative to the Year 2 Baseline Scenario. Additional, more-detailed tabular results are included for each sensitivity scenario in Appendix E.

For each of the sensitivity scenarios, all assumptions for parameter values are as specified for the Year 2 Baseline Scenario except for those factors explicitly identified as being changed. That is, "sensitivity" analyses are performed on select specified issues, holding all other things constant (HAOTC). The previous discussion attributed to Geoffrion (1976) in Perry et al. (1986) documents a principal justification for this segment of this thesis research.

Sensitivity Scenarios 1: Production For Insurance

The ability to supply the conversion facility with the required amount of biomass feedstock to operate a full year is critical to the feasibility of biomass fuels production. Unexpected disruptions in production or supply such as hurricanes, disease, fire, etc. could potentially cause the biomass conversion facility to temporarily cease operations and could financially cripple the operation. To address this issue, two sensitivity scenarios are evaluated to identify the costs of SG assumed grown for insurance purposes in this thesis research:

1A: Three extra periods of conversion facility biomass feedstock requirements; and

1B: Excess SG production equivalent to 25 percent of conversion facility biomass feedstock requirements.

Table A19 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "Production for Insurance." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B9 and B10.

The $138.42 per ton cost for the production for insurance sensitivity scenario is 103.3 percent of the $134.01 per ton cost for the Year 2 Baseline Scenario. Eliminating the requisite 40,000 acres of insurance SG (i.e., the 25 percent excess production) in Scenario 1B lowers the per ton cost to $130.02, which is 97.0 percent of the Year 2 Baseline Scenario's $134.10 per ton.

Sensitivity Scenarios 2: HES Yields

The amount of biomass that a particular biomass feedstock yields per acre is a critical factor that impacts the total cost to supply a conversion facility with biomass feedstock. Biomass feedstock yields influence the amount of acreage that must be leased and subsequently impact the machinery requirements, including production, harvesting, transportation, and storage operations. The impacts of increasing and decreasing HES yields on capital and operating costs are investigated in this sub-section. Four sensitivity scenarios are considered:

2A: HES Yield @ 8 tons/ac and no irrigation;

2B: HES Yield @ 12 tons/ac and no irrigation;

2C: HES Yield @ 18 tons/ac; and

2D: HES Yield @ 25 tons/ac.

Table A20 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- “HES Yields.” Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B11 and B12**.**

In all four of the sensitivity scenarios associated with varying expected HES harvested yields, costs per dry ton of biomass feedstock are lower than the $134.01 associated with the Year 2 Baseline Scenario. The advantages gained from not having to irrigate are spotlighted in scenarios 2A and 2B whereas the potential gains (i.e., cost savings) from substantially-higher expected yields are represented in scenarios 2C and 2D. Notable is that slightly more than doubling the harvested yield expectations in scenario 2D only lowers the cost per dry ton of biomass feedstock by 16.8 percent. Not considered are the implications related to risk.

Sensitivity Scenarios 3: SG Yields

As noted in the introduction to Sensitivity Scenario 2, "The amount of biomass that a particular biomass feedstock yields per acre is a critical factor that impacts the total cost to supply a conversion facility with biomass feedstock. Biomass feedstock yields influence the amount of acreage that must be leased and subsequently impact the machinery requirements for all production operations, including harvesting, transportation, and storage operations." The impacts of increasing and decreasing SG yields on capital and operating costs are investigated in this sub-section. Two sensitivity scenarios are considered:

3A: SG @ 2 tons/ac; and

3B: SG @ 6 tons/ac.

Table A21 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "SG Yields." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B13 and B14.

The importance of SG in the overall supply portfolio (i.e., limited to a maximum of 25 percent of the total supply) is illustrated in these results. Lowering expected harvested SG yields by one-third (i.e., scenario 3A) increases per ton costs to $140.65 (105.0 percent of the Year 2 Baseline Scenario). Doubling of the expected harvested SG yields (i.e., scenario 3B) lowers per ton costs to $126.81 (94.6 percent of the Year 2 Baseline Scenario).

Sensitivity Scenarios 4: Monoculture

Some research suggest that supplying a biomass conversion facility with a diverse portfolio of feedstocks will assist in minimizing costs due to the year-round operation of the conversion facility (McCutchen, Avant, and Baltensperger 2008**)**. The ability to select alternative biomass feedstocks that can be grown or purchased during different times of the year can potentially ease supply costs by reducing the amount of biomass feedstock that must be stored as well as reduce capital investment on transport vehicles. The costs implication of only producing a single biomass feedstock to supply the conversion facility is evaluated in this section. Two sensitivity scenarios are evaluated:

4A: Only HES for principal supply, plus 25 percent SG for insurance; and

4B: Only SG for principal supply, plus 25 percent SG for insurance.

Table A22 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- “Monoculture.” Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B15 and B16.

The comparative disadvantage of HES relative to SG in the targeted production area is apparent in these results. A monoculture HES production region (i.e., scenario 4A) results in a substantially higher $159.20 per ton cost (118.8 percent of the Year 2 Baseline Scenario). Conversely, a monoculture SG production approach (i.e., scenario

4B) would have a much lower $88.21 per ton cost (65.8 percent of the Year 2 Baseline Scenario). Although the directions of these results are not surprising (given that an upper limit of 25 percent SG was established in the Year 2 Baseline Scenario), the magnitude of the differences in cost are beyond expectations. Certainly, the greater machinery requirements associated with the more-intensive farming operations required in HES production and the high-moisture nature of HES harvest and transport are contributing factors to these results. For SG only, there is a dramatic increase in acreage requirements.

Sensitivity Scenarios 5: Costs

In this section, several scenarios are considered to identify the positive or negative implications of the estimated cost data. These scenarios are intended to account for any inaccuracies in the data estimates, revealing the magnitude of effect(s) of such impreciseness on the calculated results. Following the suggestions of Geoffrion (1976), several critical data parameters are systematically adjusted to provide insights intended to be useful in interpreting the complexities of the holistic logistics biomass feedstock production supply chain and in prioritizing future research initiatives. Twelve sensitivity scenarios are evaluated to investigate the relative importance of various cost-related factors and associated assumptions incorporated into this thesis research and its baseline scenario:

5A: Capital costs are reduced 15 percent;

5B: Capital costs are increased 15 percent;

5C: Operating costs are reduced 15 percent;

5D: Operating costs are increased 15 percent;

5E: Discount rate is reduced 1 percent;

5F: Consider only farm gate costs;

5G: Consider only "Just-In-Time" deliveries;

5H: Consider "Just-In-Time" deliveries with adjusted trafficable days;

5I: No full-time labor (only part-time);

5J: Lease all transportation (versus purchased);

5K: Periodic storage deterioration increased to 5.0 percent; and

5L: Periodic storage deterioration changed to 0.2 percent.

Table A23 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "Costs." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B17 and B18.

The results for scenarios 5A-5D are intended to represent over- and under-estimations of capital investment and operating costs, respectively. For example, capital investment costs could perhaps be lowered if viable machinery leasing or custom operations industries were to develop in support of production for the noted biomass conversion facility. Per dry ton cost estimates vary for these four scenarios from $120.68 to $148.17 (90.1-110.6 percent of the Year 2 Baseline Scenario). Notable is that the range of results are wider for the +/- 15 percent change in operating costs ($120.68 to $148.17 per ton) than for the +/- 15 percent change in capital investment costs ($128.37 to $139.56 per ton). These results should not be surprising in that operating costs are 72.17 percent of total costs in comparison to the 27.83 percent share represented by capital investments (figure B4).

The impact of a 1 percent change in the capital discount rate used in determining machinery and equipment ownership costs (from 5.75 percent to 4.75 percent) (i.e., scenario 5E) has a negligible impact of per ton costs, lowering them to $132.31 (98.7 percent of the Year 2 Baseline Scenario). The interest rate applicable to operating costs in scenario 5E was 6.125 percent, same as in the Year 2 Baseline Scenario.

Scenario 5F identifies the costs of producing and harvesting the biomass feedstocks, with the $86.80 per ton calculated cost representing edge-of-field, *sans* transportation and storage. This cost is calculated and presented to allow for comparisons with others' research which identifies similar values.

Scenarios 5G and 5H are focused on the impact of allowing only "Just-in-Time" deliveries to the biomass conversion facility, i.e., no extended storage of biomass feedstocks possible. In these scenarios, the 25 percent maximum allowed contribution of SG is relaxed (i.e., turned off – no maximum constraint imposed) and the Sorghasaurus© model is applied to estimate what biomass feedstock(s) (i.e., HES and/or 5G) to produce and deliver, and when to deliver. For scenario 5G, per ton costs are increased to $140.12 (104.6 percent of Year 2 Baseline Scenario). Conjecturing that the factors responsible for this higher estimate could be dominated by one or more limited harvest/delivery windows associated with the 75 percent probability of trafficable day estimates used in the Year 2 Baseline Scenario (and consequently, in scenario 5G), scenario 5H was designed to mitigate some of the extreme conditions perceived to be associated with the trafficable day estimates. Periodic trafficable day estimates were determined by averaging each period's original estimate of available days with similar estimates for the one period immediately before and the one period immediately after that period, thereby "smoothing" the estimates of allowed trafficable days across three periods and removing some of the extreme, limited low and high estimates. The results for scenario 5H include a $131.46 per ton estimate (98.1 percent of the Year 2 Baseline Scenario).

In scenario 5I, the impact of requiring/assuming the majority of the CBFFE's labor force is full-time is relaxed. Only part-time labor is utilized in this scenario, with the resulting per ton cost estimate being $119.48 (89.2 percent of the Year 2 Baseline Scenario).

In a somewhat-similar mode, scenario 5J considers the effects of the CBFFE leasing all semi trucks and trailers used for transporting biomass feedstocks from the field to storage instead of purchase. Per ton costs are $128.71 (96.0 percent of Year 2 Baseline Scenario).

In scenarios 5K and 5L, the sensitivity of the cost estimates to biomass feedstock deterioration while in storage is examined. In contrast to the assumed one percent per period product loss assumed in the Year 2 Baseline Scenario, the periodic loss factor is increased to 5 percent in scenario 5K. The resulting cost estimate is substantially higher at $155.88 per ton (116.3 percent of the Year 2 Baseline Scenario). Lowering the assumed periodic loss factor to 0.2 percent in scenario 5L realizes a $129.51 per ton estimated cost (96.6 percent of the Year 2 Baseline Scenario).

Sensitivity Scenarios 6: Machinery

The main factors impacting the amount of machinery and equipment that must be purchased are the size/scope of requisite field, harvesting, transportation, and storage operations and the number of trafficable days and related work hours per day that are available each period to perform such operations. In total, seven sensitivity scenarios are evaluated to investigate the relative importance of various machinery factors and associated assumptions incorporated into this thesis research and its baseline scenario:

6A: Trafficable Days at 50 percent;

6B: Trafficable Days at 90 percent;

6C: Only SG grown with Trafficable Days at 90 percent;

6D: Trafficable Days Relaxed (x10);

6E: Economics of farm size, with no SG and no insurance;

6F: Maximum HES harvest moisture set at 25 percent; and

6G: Increase transportation capacity 20 percent.

Table A24 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "Machinery." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B19 and B20.

The number of trafficable days are tightened and relaxed in this category to evaluate the impacts of the dynamics of these critical resource constraints, e.g., there being either a rainy year with limited operating hours or a dry year with numerous operating hours. Relaxing (increasing) the assumed availability of trafficable days to the

50 percent probability level (i.e., Scenario 6A) substantially enhances the production capacity of all machinery and equipment units, thereby reducing the capital investment requirements. The resulting per ton cost estimate is $114.24 (85.2 percent of the Year 2 Baseline Scenario). In contrast, constricting (decreasing) the assumed availability of trafficable days to the 90 percent probability level (i.e., Scenario 6B) substantially lowers such production capacities, consequentially increasing the capital investment requirements. The resulting per ton cost estimate is $169.36 (126.4 percent of the Year 2 Baseline Scenario).

In Scenario 6C, the intent is to calculate the cost of a SG monoculture under restricted trafficable days (i.e., 90 percent probability) to facilitate comparisons to both the Year 2 Baseline Scenario and the Scenario 4B SG monoculture analysis. Relative to the Year 2 Baseline Scenario, estimated per ton cost for Scenario 6C is $102.56 (76.5 percent). In contrast to the $88.21 cost estimate for Scenario 6C, the $102.56 value is 16.3 percent higher.

Scenario 6D represents an attempt to remove/lessen the impact of considering trafficable days, thereby establishing the economic consequences of such consideration. In this scenario, all trafficable day estimates are increased tenfold, effectively eliminating the effects of individual machinery and equipment unit capacity constraints. Removal of the trafficable days consideration in this manner results in a per ton cost estimate of $112.35 (83.8 percent of the Year 2 Baseline Scenario).

Also evaluated are the cost implications of several smaller commercial farming operations producing biomass feedstocks for the conversion facility versus a large corporate farming entity (as assumed with the CBFFE in the baseline and all other sensitivity scenarios) performing all logistics operations. Scenario 6E is intended to provide insight on the importance of economies of size. The dry ton cost estimate for this scenario soars to $261.52 (195.1 percent of the Year 2 Baseline Scenario). Influential causal factors for these results are perceived to be the integer programming requirements on machinery and equipment capital investments. Such requirements coupled with smaller-size operations' inability to spread the ownership costs of machinery and equipment over economic quantities of acreage contribute to excessive investments and resulting slack, unused machinery and equipment resource hours.

Research suggests that reducing the moisture content of biomass feedstock prior to transportation will significantly lower the costs of transporting biomass feedstocks as more biomass feedstock can be transported with less machinery. Semi trailers are constrained not only by weight, but also by the volume that can be transported; therefore, two scenarios are included to evaluate the relative gains of reducing biomass feedstock moisture content. In Scenario 6F, it is assumed some form of in-field desiccation occurs (at no cost), resulting in a maximum harvest moisture of 25 percent for HES. Consequently, HES harvesting machinery and transport capacities are increased in response to the lower density (i.e., there is less weight per cubic foot of space as HES harvest moisture declines) of the harvested HES biomass feedstock material, lowering the requisite capital investments and per unit operating costs. Resulting per ton cost estimates are $116.03 (86.6 percent of Year 2 Baseline Scenario).

Another approach to mitigating the economic consequences of transporting the vast amount of excess moisture inherent in contemporary harvested HES biomass feedstock is to increase the amount of material allowed to be transported in each load, i.e., relax the TxDOT weight limits. In Scenario 6G, transport physical capacity limits for HES are increased by 20 percent[77]. The resulting dry ton cost estimate is $129.63 (96.7 percent of the Year 2 Baseline Scenario).

Sensitivity Scenarios 7: Moderate Aggregate

The following scenarios are intended to provide insight on the potential costs reductions associated with assuming pseudo-optimistic forthcoming developments in potential harvested yields in combination with relaxed constraints regarding capital costs, availability of part-time labor, trafficable days, and transportation capacity. It is expected that increasing harvest yields in combination with increased trafficable days and increased transportation capacity will lower the per-dry ton delivered costs. In total, three sensitivity scenarios are evaluated to investigate the relative impact on costs of assuming moderately-optimistic developments related to yields, capital costs, trafficable days, and transportation capacity.

Three sensitivity scenarios are evaluated to investigate the potential reduction in biomass feedstock costs that could be achieved if parameters for several selected factors could be altered as a result of moderate research advances and improved management:

[77] The impact of weight constraints for HES biomass feedstock transport are addressed in Scenario 6F by assuming lower harvest moisture levels.

7A: 10 dry ton HES yields with no irrigation, capital costs reduced 15 percent, and trafficable days are set at 50 percent;

7B: 12 dry ton HES yields with irrigation, capital costs reduced 15 percent, and trafficable days at 50 percent; and

7C: 18 dry ton HES yields with irrigation, capital costs reduced 15 percent, and trafficable days at 50 percent.

Table A25 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "Moderate Aggregate." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B21 and B22.

Scenario 7A is a representation of inexpensive (non-irrigated and 15 percent lower capital costs), lower expectations (than in the Year 2 Baseline Scenario) for harvested HES yields, with relaxed trafficable-days constraints (i.e., to the 50 percent probability level). The resulting dry ton cost is $101.18 (75.5 percent of Year 2 Baseline Scenario).

In Scenario 7B, HES expected harvest yields are the same as in the Year 2 Baseline Scenario and irrigation is assumed. Trafficable days are relaxed to the 50 percent probability level. Per dry ton costs are $109.79 (81.9 percent of the Year 2 Baseline Scenario). These results are suggestive that the value/cost of an expected yield increase of two tons per acre of HES is insufficient to finance the added capital investment and operating costs associated with irrigation.

In Scenario 7C, the only change relative to Scenario 7B is the increasing of expected HES harvested yields to 18 tons per acre. The resulting per ton cost of $98.57 (73.6 percent of the Year 2 Baseline Scenario) is only slightly lower than the $101.18 per ton calculated for Scenario 7A. The relative comparability of these results suggests expected yield increases on the magnitude of 9-10 tons per acre are required to economically justify irrigation, ignoring the risk and uncertainty aspects of yield variability.

Sensitivity Scenarios 8: Substantial Aggregate

The following scenarios are intended to provide insight on the potential costs reductions assuming optimistic developments in potential harvested yields in combination with relaxed constraints regarding capital and operating costs, availability of part-time labor, trafficable days, and transportation capacity. It is expected that increasing harvest yields in combination with increased trafficable days and increased transportation capacity will lower the per-dry ton delivered costs. As discussed earlier, any reductions in operating costs have a significant impact on per dry ton deliver costs as operating costs make up approximately three quarters of total annual costs. Three sensitivity scenarios are evaluated to investigate the potential reduction in biomass feedstock costs that could be achieved if parameters for several selected factors could be altered as a result of substantial research advances and improved management:

8A: 10 dry ton HES yields with no irrigation, both capital and operating costs reduced 15 percent, trafficable days at 50 percent, and transportation capacity increased 20 percent;

8B: 12 dry ton HES yields with irrigation both capital and operating costs reduced 15 percent, trafficable days at 50 percent, and transportation capacity increased 20 percent; and

8C: 18 dry ton HES yields with irrigation both capital and operating costs reduced 15 percent, trafficable days at 50 percent, and transportation capacity increased 20 percent.

Table A26 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- "Substantial Aggregate." Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B23 and B24.

Scenario 8A is similar to Scenario 7A except operating costs are also reduced 15 percent and transportation capacity is increased 20 percent. The resulting per ton cost is $86.82 (64.8 percent of Year 2 Baseline Scenario) and 85.8 percent of the $101.18 estimate for Scenario 7A.

Similarly, Scenario 8B extends the advances noted for Scenario 7B by reducing operating costs 15 percent and increasing transportation capacities. For this scenario, $94.56 is the cost per dry ton (70.6 percent of Year 2 Baseline Scenario) and 86.5 percent of the $109.79 estimate for Scenario 7B.

Scenario 8C produces the lowest estimate of holistic biomass feedstock logistics costs among all scenarios considered in this thesis research. In this scenario, the advances noted for Scenario 7C are combined with the additional advantages of 15 percent lower operating costs and a 20 percent increase in all transportation capacities. $84.75 per ton is the resulting estimated cost (63.2 percent of the Baseline Scenario) and 86.0 percent of the $98.57 estimate for Scenario 7C. It is noteworthy that this calculated cost value for a recognized "substantial aggregate" realm of improvements is only slightly less than the $88.21 per dry ton estimated for the SG monoculture Scenario 4B, with that $88.21 per ton cost being realized with what many claim are very conservative expected harvested yields of 3 dry tons per acre. However, the substantial aggregate developments factored into Scenario 8C allow for a reduction in capital outlays from the Year 2 Baseline Scenario's $118.2 million and the $81.7 million estimated for Scenario 4B to only $73.7 million (table A22).

Sensitivity Scenarios 9: Miscellaneous

During the latter stages of this thesis research, several issues were discussed during and following a seminar with the thesis committee (June 24, 2011). Five select issues were subsequently investigated in contexts similar to that employed for the previous mentioned/discussed sensitivity scenarios:

9A: HES rotation acreage sub-leasing costs increased to evaluate prospects of greater returns during non-HES years;

9B Irrigation wells are owned, but not operated;

9C SG harvesting is prohibited during April and May;

9D: Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Year 2 Baseline Scenario; and

9E Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Economies of Size Scenario 6E.

Table A27 is a summary report of the critical evaluation criteria for this category of sensitivity scenarios -- “Substantial Aggregate.” Graphical comparisons of the cost per dry ton of all biomass feedstocks produced in these sensitivity scenarios relative to the Year 2 Baseline Scenario are illustrated in figures B23 and B24.

In Scenario 9A, the additional $50 per acre cash rent inflow on the HES rotation acreage resulted in a cost per dry ton of $124.26 or 90.70 percent of the Year 2 Baseline Scenario’s $134.10. All activity solution values other than the rental income are the same as in the baseline scenario solution.

In Scenario 9B, it is assumed the expected HES yields specified in the baseline scenario are achieved without the necessity of irrigation, but that the capital ownership costs are borne annually, with realized per ton costs when the wells are operated being the solution for the baseline – $134.01. In Scenario 9B, the calculated cost per ton is $124.92, that being 93.2 percent of the baseline scenario.

In Scenario 9C, SG harvesting is not allowed during April and May for agronomic purposes, allowing new growth to be established without the potential of damaging longevity of the current plantings by premature harvest. A slight increase in cost (101.4 percent of the baseline scenario) is represented in the resulting $135.83 per dry ton.

In Scenario 9D, the requirement of purchasing machinery and equipment and hiring full-time labor in whole, integer increments is relaxed, i.e., these items are assumed buyable on a continuous (i.e., non-discrete) basis. Due to the number of units of such machinery, equipment, and full-time labor involved in the relatively large-scale CBFFE, the impacts of relaxing this requirement are slight as reflected by the calculated per dry ton cost of $133.73, which is 99.8 percent of the baseline scenario's $134.01. That is, the incremental requirements of "rounding up" such purchases are minimal in a relative sense.

In Scenario 9E, relative to Scenario 9D, the analysis entails identifying the impacts of relaxing similar integer requirements on the smaller-size farms analyzed in the Economies of Size, Sensitivity Scenario 6E. The calculated per dry ton cost for Scenario 9E is $236.71, which is 176.1 percent of the baseline scenario's $134.01, but it is only 90.2 percent of the $261.52 per dry ton estimated for Scenario 6E.

Summary of Nine Sensitivity Scenario Categories

Table A28 is an abbreviated listing of the optimal Sorghasaurus© cost-minimizing results for the Year 2 Baseline Scenario and the 39 sensitivity scenarios incorporated into the aforementioned nine categories. Figure B27 is an illustration of the associated cost per ton estimate arranged in ascending order, left to right. Figure B28 is a similar illustration, but with the results for Scenario 6E and 9E excluded (due to their distorting influence on the scale of the figure due to its higher value relative to the other estimates).

Of importance in interpreting the results of this thesis research is recognition that:

- The Year 2 Baseline Scenario's $134.01 is NOT the definitive cost for producing biomass feedstock in the targeted Middle Gulf Coast, Edna-Ganado, Texas area;
- There is a range of cost estimates ($84.75 - $261.52 per dry ton) for this targeted study area, with the exact value dependent on and sensitive to numerous assumptions associated with the potential performance of various aspects of the CBFFE's production-harvest-transportation-storage logistics paradigm;
- All of the cost estimates represented in this $84.75 - $261.52 per dry ton range exceed the popular $50 - 60 per ton estimate identified as the maximum possible cost for cellulosic biomass feedstock conversion processes to be economically attractive (McCutcheon, Avant, and Baltensperger 2008);
- The results presented in this thesis research are relevant for the Middle Gulf Coast, Edna-Ganado, Texas area and the numerous assumptions made related to HES and SG logistics, i.e., the results are not intended to be extrapolated and interpreted as representing other geographical areas and/or alternative types of celluslosic biomass feedstock logistics, but the approach utilized is extendable to other circumstances; and
- Collaborative focus of agricultural economists, soil and crop scientists, and agricultural engineers toward enhancing the form of activity/resource linkage

and requisite data and accuracy thereof to facilitate use of the economic analysis approach embodied in Sorghasaurus© is a worthwhile research endeavor.

In table A29 and figure B29, the categorical holistic farm production-harvesting-transporting-pre-refinery storage supply chain logistics costs for the Year 2 Baseline Scenario (panel B29a) are presented first, allowing comparison of similar cost breakdowns for Scenario 8C (the lowest per ton cost estimate identified in this thesis research) in panel B29b and for Scenarios 6E (the highest per ton cost estimate identified in this thesis research) in panel B29c. The categorical patterns of expenditures are remarkably similar across the three scenarios. The observed costs for the harvesting, transportation, and storage components of the holistic farm production-harvesting-transporting-pre-refinery storage supply chain logistics system are in all cases lower than the 22.6 percent for harvesting and the 38.6 percent for transportation and storage reported by U.S. Environmental Protection Agency (2009). It is conjectured the observed differences in this thesis research may be attributable to its lower per acre yields than those used in the U.S. Environmental Protection Agency (2009). Because of the tendency of harvest, transportation, and storage costs to vary on a per ton basis versus the per acre nature of production costs, a greater (lower) volume and resulting proportion of total costs are associated with higher (lower) yields.

ECONOMIC IMPACT ANALYSIS

The IMPLAN input-output model (Minnesota IMPLAN Group 2009) serves as a valuable tool to estimate the economic and employment impacts of establishing a corporate farming operation in the Middle Gulf Coast, Edna-Ganado, Texas area for the production of cellulosic biomass feedstocks (HES and SG, Year 2 Baseline Scenario) for energy conversion. The impacts are estimated for a ten-county region surrounding Middle Gulf Coast, Edna-Ganado, Texas including: Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria (figure B30). For this case study, the IMPLAN model is applied to estimate the direct, indirect, and induced impacts associated with exogenous changes in economic activity due to the introduction of this new bioenergy sector[78] (Minnesota IMPLAN Group 2009). Changes in economic output, value-added, and employment can also be estimated at a county, state, and national level for the farming activity and does not include any conversion factors. Such estimation is accomplished through the use of multipliers, which represent the expected economic and employment impact from a change in a given economic activity.

Three main multipliers are used in this study: (1) economic output, (2) value-added, and (3) employment. **Economic output** is a measure of gross business activity or the total value of goods and services. The economic output multiplier measures the change in gross business activity resulting from a change in final demand. **Value-added**

[78] Direct economic impacts consist of the cost directly associated with the initial startup phase and post startup phase. Indirect impacts result from supporting industries supplying inputs to the farming operation (fuel, fertilizer, etc.). Induced impacts account for economic activity resulting from the spending of wages associated with the farming operation.

is the contribution to the gross domestic product (i.e., gross output minus purchases of inputs from other sectors) for the region. It reflects the value added through the production process. This multiplier measures the change in gross domestic product resulting from a change in a given economic activity. **Employment** measures the number of full-time and part-time jobs that are expected to be created. Employment multipliers evaluate the change in the number of jobs per million dollars of output (Seawright 2009).

Impact analysis is used to evaluate the economic and employment effects of capital expenditures associated with the startup phase of the operation (e.g., initial capital investments), and the annual impacts associated with the operation after the startup phase (e.g., annual operating expenses). Since Sorghasaurus© is developed as a cost-minimization model and the income stream is not modeled for the sale of HES or SG, economic and employment impacts are measured as the difference between cow/calf enterprise income displaced and HES and SG capital and production costs. That is, a consecutive approach is taken and it is assumed that the value of the HES and SG produced is, at a minimum, equal to their costs at the frontgate of the conversion facility. The income generated from a cow/calf enterprise is used as the base in this analyses because it is assumed that HES and SG will be produced on pasture land, thus altering the use of that land and displacing the cattle.

Texas AgriLife Extension Service (2009c) enterprise budgets for District 11 are applied to estimate the income displaced by converting pasture land historically used for cow/calf production into HES and SG crop land. Acres converted into HES and SG crop land are divided by the stocking rate for Extension District 11 (historically 4.5 to five acres per animal unit (cow-calf)) to estimate the number of cows displaced (Falconer 2009)[79]. The number of animal units displaced is then multiplied by the gross income generated per cow to obtain the total gross income (returns) displaced by changing land use from pasture to HES and SG crop land. Using the cattle sector in IMPLAN, the estimated cow-calf income displaced represents the direct impact (i.e., change in final demand).

HES and SG capital and production cost are divided into individual market sectors (i.e., fuel, repair and maintenance, fertilizer, etc.) so multipliers for each sector can be applied[80]. Multipliers for economic output, value-added, and employment (table A30) are applied to these cost categories and the cow/calf income to determine the impacts of producing cellulosic biomass feedstock in the ten-county region for the startup year and the following year as compared to traditional cow-calf operations. For example, the economic output multiplier for road base is 1.98, indicating that $1.98 of economic activity is generated for each $1 spent on road base cost. A value-added multiplier of 0.98 means that each dollar spent on road base will generate $0.98 in value-added. The employment multiplier indicates that 6.83 direct jobs and 5.87 indirect and induced jobs are supported per $1 million increase in road base cost.

HES and SG capital and production costs (i.e., direct costs), economic output, value-added, and employment generated for the ten-county region by producing HES and

[79] The stocking rate for district 11 is one animal unit (cow-calf) to every five acres.
[80] Since Machinery and Equipment was identified as a wholesale sector and Fuel Expenses were identified as a retail sector, the direct impacts of these sectors were adjusted for cost of goods sold (margins).

SG in Middle Gulf Coast, Edna-Ganado, Texas area for the startup year are displayed in table A31. The direct cost of producing HES in the Middle Gulf Coast, Edna-Ganado, Texas area is $118.25 million for capital investments and $38.66 million for annual operating expenses. The total economic output generated by capital investments and operating expenses required for the production of HES and SG is $194.74 million and $70.16 million, respectively. The valued-added to the ten-county region is estimated at $121.53 million for capital investments and $37.41 million for operating expenses. This level of impact supports the additional employment of 1,117 jobs (full-time equivalents) related to capital investments and 964 jobs related to operating expenses. Thus, the total economic output, value-added, and employment impacts generated in the region by producing HES and SG in the startup year is $264.90 million, $158.94 million, and 2,081, respectively.

Since the capital investments occurred in the first year, impact analysis in year 2 consist of assessing the impacts of only operating costs. Since, Sorghasaurus© is a single-period model (i.e., one year) and is not equipped to forecast prices, it is assumed that operating expenses for year 2 will be the same as the startup year. Therefore, the economic output, value-added, and employment impacts generated in year 2 is $70.16 million, 37.41 million, and 964, respectively.

The annual direct impacts, economic output, value-added, and employment generated for the region by displaced cow/calf production is displayed in table A32. A total of 110,535 acres of pasture land is converted into HES cropland while a total of

77,225 acres of land is converted into SG cropland[81]. Thus, by using a stocking rate of five acres per cow, 37,552 cows will be displaced. Annual income generated per cow of \$435.72 was used to estimate the gross value of cow-calf income displaced (Texas AgriLife Extension Service 2009c); therefore, by multiplying the number of cows displaced by the income generated per cow, the direct impact is estimated at \$16.36 million (Texas AgriLife Extension Service 2009c). The annual economic output, value-added, and employment generated by the cow/calf enterprise is estimated to be \$29.14 million, \$9.48 million, and 456, respectively. It is assumed that the direct impact for year 2 will be the same as the direct impact in the startup year.

As presented in table A33, the net gain from producing HES and SG instead of cattle for the startup year is \$140.55 million for the ten-county region. The net gain in economic output, value-added, and employment for the year is \$235.76 million, \$149.46 million, and 1,624, respectively. When considering the annual operating impacts after the startup year, the net gain in economic output for year 2 is \$41.02 million, for value-added it is \$27.93 million, and for employment is 508, respectively (table A34). Thus, by producing HES and SG instead of cattle, the level of economic activity in Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria counties substantially increases. The economic impacts of setting up a corporate farming operation for the production of HES and SG are highly positive. These estimated economic and employment impacts are a function of the structure of the economy and

[81] Because a three-year rotation is used for HES, 36,845 acres is multiplied by 3 years to determine the total acreage. SG acreage includes SG land used for production and SG land used for insurance.

any projects to the future would assume the same structure. In reality, the economic structure is dynamic going through evolutions as technology and relationships adjust; hence, future impacts would be expected to be different.

CHALLENGES, LIMITATIONS, AND FUTURE RESEARCH NEEDS

There are significant challenges facing the integration of biomass feedstocks into a cost-competitive supply system. The absence of an infrastructure capable of producing sufficient dedicated biomass feedstocks to supply an economically-viable conversion facility is a major challenge facing the biofuels industry. This lack of infrastructure is particularly apparent in localized targeted biofuel production areas/regions. The challenges and limitations presented in this section provide insight on the areas where further research and development are needed to improve the economic and financial competitiveness of biomass feedstocks with petroleum.

Cellulosic Biomass Feedstock Spot Markets

Spot markets, similar to that existing for corn grain or other commodities, provide demanders with an efficient mechanism to obtain an immediate supply of biomass feedstock at an efficient price. Currently, there are no spot markets for cellulosic biomass, so conversion facilities must rely on production areas located in close proximity to the plant for supply. To obtain a stable supply of biomass feedstock, conversion facilities could engage in: (1) contracting with individual growers, (2) using a cooperative arrangement to contract with a group of growers, (3) arrange long-term land leases such as Conservation Reserve Program leases, and/or (4) purchase crop land (Epplin et al. 2007). The production of dedicated energy crops must be equally as profitable as conventional crops for any of these options to be viable and to induce farmers to produce dedicated energy crops instead of the next best alternative (Walsh 1994; Fumasi, Richardson, and Outlaw 2008). Fewell, Bergtold, and Williams (2011) suggest additional incentives may be required to realize such land use conversion by producers.

Cellulosic Biomass Feedstock Storage Degradation

Loss of quantity and quality of biomass during storage is just one more challenge facing the biofuels industry. Storage is a necessary component of the biomass feedstock supply system because dedicated biomass feedstocks typically have a narrow harvest window compared to the year-round need of the conversion facility. Moisture content plays a major role in biomass degradation and studies indicate decreasing moisture levels to less than 15 percent will aid in the preservation of the material. Idaho National Laboratory estimates dry matter loss must be reduced to less than five percent to meet government and private sector cost goals (Hess, Wright, and Kenney 2007).

High-Energy Sorghum Moisture Content

A major hurdle in minimizing the cost to supply a biomass conversion facility with HES is the high-moisture content of the harvested crop. HES harvested for silage with no field drying time has a moisture content ranging from 60 to 75 percent, depending on the season and growth stage. The moisture content in the fall season is difficult to predict as it is not dependant on the crop itself, but is also dependant on weather patterns. The high-moisture content increases trucking costs due to state regulations. For example, the

Texas Department of Transportation's load limits (achieved with maximum transport trailer capacities) result in a substantial number of loads of wet material being hauled to the conversion facility to obtain a sufficient amount of dry material to meet minimum daily plant requirements. A somewhat effective method for reducing the moisture content is terminating the HES plant with a herbicide prior to harvesting. This technique reduces the moisture, but not on a scale that makes it an extremely attractive option, plus involves added production costs (Rooney 2010).

Another option for reducing excessive moisture transport is cutting the HES and allowing it to field dry. This could reduce the moisture content to 45 to 55 percent, but soil is picked up when the biomass feedstock is harvested, which reduces the conversion efficiency of the biomass feedstock. This method also produces higher field losses than other techniques, averaging around 10 percent (Blumenthal 2010). Further, the potential of high rainfall events during the harvest season in some locations (Raun 2010; Leidner 2010) suggests caution is appropriate with respect to pursuing in-field drying of mowed biomass feedstock. Also, there is the threat of lodging due to rain and wind, further reducing potential yield.

Biomass Feedstock Portfolio

A diverse portfolio of biomass feedstocks will most likely be required to supply a biomass conversion facility because it is intended to operate year-round. There are a variety of alternative biomass feedstock sources available near[82] the Middle Gulf Coast, Edna-Ganado, Texas area such as forestry residues, rice hulls, rice straw, gin trash, Coastal Bermuda hay and milo/corn hay (Carraway 2009; Popp 2010; Raun 2010). Most of these sources have large secondary markets and are expensive to acquire. The availability of these biomass feedstocks is dependant on a variety of factors outside the control of the conversion facility and, thus, the conversion facility cannot solely rely on these sources for supply. These alternative sources must be supplemental to the dedicated biomass feedstocks grown specifically for biofuels production by the conversion facility. Targeting specific production regions sets boundaries on biofuels production/sourcing opportunities as well as opportunity costs related to existing enterprises. In addition, when alternative sources come into play will typically be those times the dedicated feedstock is in short supply due to factors that also impact the alternative. It is expected there will be serious pressure on all feedstock alternatives.

Conversion Efficiencies of Alternative Biomass Feedstocks

There is a considerable variation in the conversion efficiencies of alternative biomass feedstocks (Rooney 2010). The conversion efficiency is based on the composition of the biomass feedstock and on the growth stage of the plant. For HES, soluble sugars are low during the early growth stages and increase until mid-September when they spike, whereas lignin increases throughout the growing season (Rooney 2010). The varying

[82] "Near" is intended to mean within 150 miles of the Middle Gulf Coast, Edna-Ganado, Texas area evaluated in this thesis research.

composition of the biomass feedstocks makes it difficult to supply the conversion facility with a consistent quality of biomass feedstock. For conversion facilities to be efficient and cost competitive, a form of quality control reducing inconsistencies in biomass feedstock composition and moisture content will be required. In this thesis research, the conversion efficiencies of HES and SG are assumed equivalent throughout the year. However, the Sorghasaurus© model is capable of accounting for differences in such efficiencies if they can be specified by the model user(s).

Switchgrass as an Insurance Strategy

The assumed approach in this thesis of producing SG for non-HES periods and/or as an insurance strategy ignores the possibility of purchasing coastal bermuda hay from area producers (Falconer 2011). But as mentioned, if the dedicated feedstock is in short supply, then it is expected the alternatives (e.g., bermuda hay) will also be in short supply and thus very expensive. As noted in the thesis, there are numerous reasons for the approach taken, but it is recognized further investigation of an appropriate insurance strategy is appropriate, given the limited availability of objective knowledge of (1) the existing hay market in the area where during drought or weather extremes is associated with ever-increasing prices and (2) the responsiveness/capability of area producers to supply requisite quantities inasmuch as needed times for such would probably correspond to production issues in the hay sector similar to HES and SG production problematic issues. Certainly, the potential of relying on Coastal Bermuda and other forages, including Johnsongrass (*Sorghum halepense*) are deserving of further attention.

Another potential issue related to SG is the assumed yield level. The assumed yield is based on a review of literature and discussion with researchers across several states. But, it is only fair to acknowledge other studies are using significantly higher per acre yields. A higher SG yield would improve the economics results of this thesis as evidenced by the sensitivity scenario which evaluated this issue, but not to the degree probably anticipated by many.

Switchgrass Costs

Several concerns are relevant in regards to the accuracy of the costs associated with SG biomass feedstock production in the targeted study area, recognizing the various assumptions made as a result of the dearth of available pragmatic data. During the latter stages of this thesis research, Rooney (2011) noted several areas worthy of further investigation:

- The assumed single planting of SG for stand establishment may understate what could be the need for seeding some/much of the acreage twice (or even three times) and over two years;
- The ten-year life cycle assumed in this thesis research may be excessive, with perhaps a six-year life cycle more realistic;
- In actual practice, planting of SG would not occur during the initial year but rather be phased in over time as allowed by availability of custom services, weather conditions, etc.;

- SG harvest should not be allowed during the initial spring or extended spring/early summer regrowth periods (e.g., April and May or March-July)[83] – the consequences of doing so need to be quantified as should the prospects for doing a proportion of the SG harvest during those months in association with the last year of the respective acreage's life cycle;
- The management of SG insurance acreage is deserving of attention in regards to whether or not, and if so how, it is fertilized and treated with herbicides; and
- The consequences of lengthened SG harvesting schedules in association with lowered heat units available for field drying during fall and winter months should be evaluated.

Trafficable Days

Risk associated with trafficable days is included in this thesis research to illustrate how weather can impact timing of field operations. This feature of the research provides insight to field timing and yield. Not included are the risks of hurricane or other catastrophic weather events which have the potential of driving yield to near zero. Such an event represents a major threat to the cash flow and sustainability of biomass feedstock supply.

[83] At the suggestion of Rooney (2011), other Texas AgrLife Soil and Crop Science faculty are being contacted to resolve this issue for subsequent applications of Sorghasaurus©.

In addition, the trafficable day estimate used in this research originated during the mid 1970s in association with research by Whitson et al. (1981) and Bordovsky (1979) in the Corpus Christi, Texas area. Should more research of the type noted in this thesis be pursued, these estimates should be updated and the protocol applied to other geographic regions as well.

High-Energy Sorghum Dryland Yield Curve

Uncertainties exist in regards to feasible HES, SG, and other biomass feedstock production yields in localized areas; that is, there is not an abundance of localized production yield data for biomass feedstocks (Blumenthal 2010; Rooney 2010). The yield data used in this thesis research are experts' subjective estimates based on research plots across much of Texas, including the detailed planting date/harvest date harvested yield/harvest moisture content relationships assumed. These data are critically important in terms of their effects on bottomline delivered biomass feedstock costs and, consequently, are deserving of attention in future research relations. Site-specific field trials in areas for which construction of biomass conversion facilities is being considered are a worthy consideration for further research.

Availability of Land for Biomass Feedstock Production

A majority of the land ideal for crop production is already used to produce food and fiber crops for animal and human consumption. Acquiring this land for the production of biomass feedstocks would require significant cost, potentially making this approach cost prohibitive. Thus, it is perceived marginal land (e.g., pasture) will have to be used to produce biomass feedstocks which will reduce the yield potential and increase the production cost of biomass feedstocks.

According to Lee (2010), there are 1.2 million acres of improved pasture/grassland within a 60-mile diameter circle centered along U.S. Highway 59 between Edna and Ganado, just west of El Campo, Texas. Recognizing the more than 110,535 acres of HES (in a three-year rotation), the approximate 37,225 acres of SG required to supply the 30-million gallon conversion facility year-round, and the approximate 40,000 acres of insurance SG acreage, suggest a total of 187,760 acres or 12.5 percent of this total 1.2 million acres is required to support the conversion facility. An emerging demand of this magnitude for such acreage potentially could affect the land rental market and, thus, result in the land cost estimates used in this thesis research to be an understatement of what might actually occur.

Crop Rotation Semantics and Economics

Exactly how production of HES and SG would be implemented in the Middle Gulf Coast, Edna-Ganado area is subject to debate. In this thesis research, it is assumed that a three-year rotation would be used for HES production, with one year of production and two years of rotation out of production. Pasture is assumed to be the norm during the out-of-HES production years, with entities other than the CBFFE subleasing the acreage in those years and being responsible for all cultural and grazing activities. A simplified sensitivity analysis was enacted late in the thesis research exploring the potential impacts of greater rental income being associated with field crops being grown by the subleasees. The scope of production systems and the extent to which one or multiple entitiy(ies) actually perform which cropping activities are deserving of additional attention in the future.

Irrigation

A basic assumption of this thesis research is that HES production will require supplemental irrigation during the immediate post-planting stages, for all planting periods. There is some speculation that might not be the case, particularly for late spring planting periods (Rooney 2011). Further investigation of the weather data provided by Raun (2010), perhaps with a growth model, appears appropriate, given the magnitude of capital investment required for irrigation wells and the nature of the results associated with sensitivity scenarios focused on this issue. The current context of irrigation in this thesis research is that it is assumed to reduce risk and, therefore, much of the costs are in investment to establish stands, suggesting only marginal costs to actually irrigate. Further, it is potentially possible that irrigation costs are overestimated because it is assumed the wells are used only on HES during an extremely limited period of time – could those wells be used on other crops during other periods of the year (and the associated fixed costs spread a bit)? However, it is also assumed that the investment in wells and canals for one year's production would be sufficient and capable of reaching all HES; e.g., irrigation infrastructure for about 37,000 acres in year one will also handle the second and third year acres. A more in-depth exploration of these topical issues are warranted.

Storage Operations

This thesis research assumed and accounted for the costs of delivering and storing high-moisture content HES at the front gate of the biofuel refinery. The costs of removing excess moisture prior to the conversion facility process and management of such excess moisture disposal are ignored in this research's cost estimates[84]. The exact magnitude and relative importance of such costs are dependent on the method of removal, but could require construction of evaporation ponds or other disposal means. However, storage costs may be overestimated for dry SG biomass feedstock as most probably the bunkers would not be needed, but some form of tarp cover would be. Future research should examine these elements of the holistic biofuel logistics supply chain costs, possibly including a more explicit interface with the conversion facility.

Temporal Land Productivity

There are implications of harvesting the maximum biomass from an acre of land even if it will be fallow for the following two years. The organic matter of the soil will be depleted, impacting the sustainability of production, requiring ever greater levels of

[84] Additional discussion of this issue is included in the Storage Operations section of the baseline data presented in Appendix D.

fertilizer nutrients. Not considered in this analysis is the temporal increase in fertilizer nutrients required to maintain yield of biomass.

Environmental Implications

The level of irrigation has implication for groundwater, but also of importance is the impact of fully harvesting above-ground biomass and resulting soil erosion and runoff with nutrients and pesticides. Elevated levels of nutrients in the runoff can have serious consequences to streams and water bodies causing algae blooms and depleted oxygen levels. Adusumilli et al. (2011) is investigating this externality issue.

Policy Issues

There are a myriad of potential policy implications associated with the types of results presented in this thesis research. For the environmental impacts which are externalities imposed on the community and society, there is a need to explore policies to internalize the externalities. This suggests a means for producers of biomass feedstock to implement best management practice to mitigate the erosion and runoff of nutrients and pesticides (e.g., research in progress by Adusumilli et al. 2011). In addition, water law and regulations are dynamic in many regions of Texas and the U.S. Of particular importance is the discussion regarding groundwater in Texas and is it property of the landowner or is "the right of capture" to prevail (Texas Legislature Online 2011). These are decisions that rest with the Texas Legislature. This may have crucial implications in selected regions of Texas to the point of restricting pumping. Similarly, the contemporary move to reduce/eliminate biofuels subsidies (e.g., Dlouhy 2011) has interesting policy and biofuels demand/supply implications. The Renewable Fuels Standard (RFS) has been reduced by the U.S. Environmental Protection Agency (2011), but how they react in the future is unknown, simply adding one more element of risk and uncertainty. The value of, and need for, comprehensive economic and policy-oriented research to complement production initiatives are critical to avoiding subsequent poorly-defined investment in and operation of biofuel production systems. With current and nearby anticipated production technologies, potential economic viability of cellulosic dedicated biomass feedstock crops is dependent on subsidies and/or the RFS. Further, issues related to permitting and other legal ramifications were ignored along with potential issues of liability.

Global Climate Change (GCC)

GCC is not explicitly addressed in this research. Depending on the future scenario one considers, GCC could dramatically impact the results. For a drier scenario, but with more severe storms, increased irrigation may be required along with a greater risk of major yield losses due to storms and high winds. There are multiple future scenarios associated with GCC, with each having a different potential impact.

Alternative Fuels

The world is actually relatively new to investigating alternative future fuels. The initial response was feed grains and biomass to a mobile fuel. But, there is significant research underway that has the potential to preempt both feed grains and biomass as energy biomass feedstocks. There is the potential of a totally-different paradigm based on fuel cells as hydrogen fuel cells, electricity, methanol, natural gas, or another has yet unidentified option(s).

Energy Balance Calculations

A topic of interest in biofuels production is that of energy balance; that is, how much energy is being used and how much is being produced? (Pimental and Patzek 2005). An attempt was made during this thesis research to include appropriate metrics within the structure of Sorghasaurus©, but several elements of the energy accounting paradigm remain incomplete, including several critical data:

- How much energy is consumed to manufacture each piece of machinery and equipment required by the CBFFE? A detailed, by crop, approach is required because HES requires considerable more machinery and equipment than SG. Attention to inclusion of the semi-truck and trailers is also important. Recognition of expected useful lives of all such machinery and equipment is relevant as such lives may be different than that assumed by Pimental and Pimental (1996);

- How much energy is consumed to manufacture irrigation wells and storage bunkers? That information plus allowances for the fabrication and installation of wells and the construction of the storage bunkers should be incorporated into the energy balance metrics;
- The BTUs associated with variable inputs (e.g., fertilizer, herbicide, HES seed, fuel and lubrication, baling twine for SG) must be recognized; and
- The energy consumption associated with all custom SG field operations is relevant.

Efforts to identify and obtain accurate energy consumption and production data as well as organize such data into an understandable form of information is an important aspect of future use of Sorghasaurus©.

Summary of Challenges, Limitations, and Future Research Needs

It is acknowledged that there are several and serious limitations associated with this research. These limitations have the potential impact of either increasing or decreasing costs of production; hence, it is argued there may be some evening out of the consequences. Even with the limitations, this research extends the analysis of costs of cellulosic biomass feedstock from simply extrapolation of crop enterprise budgets to a dramatically more-realistic level, overcoming the major serious shortcomings of most previous studies.

CONCLUSIONS

In conclusion, the research reported in this thesis provides a state-of-the-art comprehensive analysis of the holistic farm production-harvesting-transporting-pre-refinery storage supply chain paradigm which represents the totality of important issues affecting the conversion facility front-gate costs of delivered biomass feedstocks. The analysis dramatically extends the complexity of most studies on costs of supplying biomass by developing a detailed model of activities, constraints, and goals. Several conclusions are apparent in reviewing and comparing the results from the baseline and several sensitivity scenarios. This section is intended to provide some generic conclusions not often recognized in other cellulosic-based biomass feedstock studies.

- The biomass feedstocks cost estimates derived in this thesis vary substantially (and tend to be higher) from those previously estimated for corn, forest residue, municipal solid waste, HES, and SG (exhibit C1). Such results either arise because the biomass feedstock sources and associated supply logistics economics are less favorable in the targeted Middle Gulf Coast, Edna-Ganado, Texas study area and/or the methods for calculating costs are more comprehensive in this thesis, identifying aspects of the logistics costs not accurately captured in the cited literature. Typically, a crop enterprise budget is extrapolated for the cost estimates, ignoring issues of timing, yield reductions from non-optimal planting/harvesting, and major logistical constraints that all contribute to higher costs.

- Cost minimization optimization which recognizes tradeoffs in capital investments versus operating costs (i.e., input substitution) is a valid and insightful approach to investigating the economics of the holistic production-harvesting-transportation-storage supply chain system.

- Inclusion of the effects of trafficable field days and the opportunity to schedule/restrict production and related operations within model-user-designated time periods affords identification of issues perhaps otherwise overlooked or represented as insignificant in importance in other studies.

- Maximum-expected yields are not realized on average across all biomass acreage due to harvested yield tradeoffs associated with timing of field and related operations subject to availability of machinery and equipment resources.

- Maintenance of additional storage inventory and upkeep of additional biomass feedstock production acreage to protect (insure) against delays in deliveries or lower than expected harvest yields is costly.

- Attempts to supply the conversion facility solely with regionally-grown HES biomass feedstocks is expensive compared to supplying the conversion facility with only SG biomass feedstocks.

- Beyond-the-farmgate costs account for more than 35 percent of the total-delivered costs while production and harvest of the biomass feedstock represent just under 65 percent of the costs, not including any conversion costs.

- Using only part-time labor (as opposed to mostly full-time labor) lowered delivered biomass feedstock costs by 10.8 percent (by $14.53 per dry ton).

- The level of assumed (actual) trafficable days can significantly affect the results in terms of dollar per dry ton delivered costs for biomass feedstocks – however, in all scenarios, costs remained above $100 per dry ton.

- Consideration of smaller farm sizes in the magnitude of 2,500 acres as opposed to the baseline scenario's assumed large-scale corporate farming entity resulted in almost doubling the per dry ton delivered biomass feedstock costs (to $261.52, an increase of 95.1 percent). This assumes the farm must purchase needed machinery, suggesting that for an existing farm already having its machinery the costs may be less.

- Targeting specified production regions for development of a cellulosic-based biofuel conversion facility sets boundaries on biomass production/sourcing opportunities as well as opportunity costs related to existing enterprises. As supported by Fewell, Bergtold, and Williams (2011), the inclusion of incentive payments to landowners to entice the conversion of what is now pasture land to biomass production is an explicit consideration in this thesis research.

- There are uncertainties regarding feasible production yields in localized areas.

- There exists limited infrastructure for this scale of operation in the targeted Middle Gulf Coast, Edna-Ganado, Texas area. This suggests major pressure on local road systems at the peak of HES harvesting.

- The relative conversion efficiencies of alternative biomass feedstocks are deserving of additional research, particularly in regard to the extent to which such efficiencies may affect the production-level decision choice of biomass feedstocks in the context of a holistic supply chain such as that used in this thesis research.

- The potential impact of water use as well as increased nutrient and sediment runoff associated with biomass feedstock production fields and management disposal of excess moisture removed during the biorefining process are deserving of in-depth research investigations.

Evaluation of Hypotheses

The hypotheses of this thesis research are:

Ha_0: Dedicated cellulosic biomass feedstocks can be produced and delivered to a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area at an economically and financially feasible cost that is competitive with other alternative sources; and

Ha_1: Dedicated cellulosic biomass feedstocks cannot be produced and delivered to a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area at an economically and financially feasible cost that is competitive with other sources;

and

Hb_0: A diverse portfolio of biomass feedstocks is required to secure a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with a continuous, year-round supply of biomass feedstock; and

Hb_1: A diverse portfolio of biomass feedstocks is not required to secure a biomass conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with a continuous, year-round supply of biomass feedstock.

In consideration of the objectives stated by policymakers, the economic literature results reported by other researchers, and the assumptions of this thesis research, the Ha_0 is rejected in favor of the Ha_1; that is, it appears, with the current state of technology, it is uneconomical to produce cellulosic biomass feedstocks in the Middle Gulf Coast, Edna-Ganado, Texas area. That is, the costs estimated in this research for delivering biomass feedstocks to the frontgate of a cellulosic facility are much higher than the $35 per ton DOE suggests is needed. The several sensitivity scenarios evaluated in this thesis research provides insights in regards to needed degrees of advancements required to enhance the potential economic competitiveness of biomass feedstock logistics in this area.

In evaluating the second set of hypotheses, the results are inconclusive. While consideration of a HES monoculture appears cost prohibitive (and thus favors rejection of Hb_0 and acceptance of Hb_1), the results for a SG monoculture are relatively more promising (suggesting Hb_0 be accepted). Consideration of a larger and more diverse set of alternative biomass feedstocks is warranted to more properly appraise this set of hypotheses.

Summary of Conclusions

There are several prior studies related to costs to supply cellulosic biomass feedstock for conversion to fuel. This analysis takes a dramatically-more-detailed view of more real-life challenges such as trafficable days, machinery and labor constraints, and seasonal harvested biomass feedstock yield relationships, balancing costs against timing and need for an imbedded insurance capability. The serious misconceptions and underestimates of costs based on a simplistic approach of extrapolating from crop enterprise budgets are clearly exposed in this thesis. In addition, the total experience among the collaborators was very rewarding while developing the model, identifying the appropriate data, conducting and interpreting analyses of the baseline and subsequent sensitivity scenarios, assembling the several conclusions, and recognizing the limitations, challenges, and needs for future research.

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APPENDIX A

TEXT TABLES

Table A1. Tons of Forest Residue Available for Biofuels Production in Texas and Louisiana, 2009.

	$30 per dry ton[a]	$45 per dry ton	$70 per dry ton
	Tons		
Texas	2,044,938	2,111,876	2,180,841
Louisiana	4,146,788	4,205,963	4,295,044

Source: U.S. Environmental Protection Agency (2009).

[a] The prices only reflect the cost of the raw source forest residue.

Table A2. Municipal Solid Waste Source and Contribution to Total Waste Stream in Texas, 2008.

Source	Percentage[a]
Residential Debris	35%
Commercial Debris	33%
Construction & Demolition Debris	19%
Class 2 & 3 Industrial Waste	5%
Sludge	2%
Brush	2%
Soil	1%
All Others	3%
	100%

Source: Comptroller's State Energy Conservation Office (2008).

[a] These percentages represent the proportional contribution of each source of MSW to the total waste stream in Texas for 2008.

Table A3. Structure of Descriptive Tables Used to Present the General Design of Sorghasaurus©, 2010.

Table 4a [a]	Table 4b	Table 4c	Table 4d	Table 4e	Table 4f	Table 4g
Table 4a. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Capital, Headquarters, Land, Machinery, and Labor, 2010.	Table 4b. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Irrigation, and HES Field Operations 1 - 11 Always Planting, 2010.	Table 4c. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for HES Field Operations 12 - 19, Closing Land Loop, SG Field Operations, and Transport HES, 2010.	Table 4d. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Transport SG, Purchase and Delivery of Alternative Feedstocks, Storage, and Cellulosic Plants Periodic Requirements, 2010.	Table 4e. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Transfer Unused Tractor Hours and Overhead Management, 2010.	Table 4f. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for RHS and Constraints, 2010.	Table 4g. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for RHS signs and Constraints, 2010.

[a] Tables 4a - 4g are presented and discussed subsequently in this chapter with sufficient detail so the reader can discern the method of operation and model structure. The information presented in this table for each of the table 4s are the respective table titles.

Table A4a. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Capital, Headquarters, Land, Machinery, and Labor, 2010.

Constraints	Activities						
	Borrow Money	Purchase Headquarters	Rent and Purchase Land	Purchase Machinery	Lease Machinery	Hire Full-Time Labor	Hire Part-Time Labor
Minimize Objective Function	+[a]	+	+	+	+	+	+
Dollar Resources	-[b]	+	+	+	+	+	+
Headquarters		-	+	+			
Land Resources		+	+/-				
Close Loop							
Machinery Leasing					+		
Labor Resources						-	+/-
Groundwater Resources							
Surface Water Resources							
All Irrigation Water							
Re-Lift Pumps			+				
Machinery Resources				-	-		
Field Work Transfers 1 - 10							
Field Work Transfers 10 to 11 Always Planting							
Field Work Transfers 11 Always Planting to 12 - 17							
Field Work Transfers 17 to 18 Always Harvesting							
Field Work Transfers 18 Always Harvesting to 19 - Close Loop							
Link Planting and Harvesting							
Transfer Harvested HES to Storage							
Transfer Harvested SG to Storage							
Purchase Transported Alternative Biomass feedstock							
Purchase Delivered Alternative Biomass feedstock							
Storage Capacity							
Transfer All Biomass feedstocks to Conversion Facility							
Required HES and SG Production							
Periodic Conversion Facility Requirements							
Restrict Capital Investments				+			
Overhead Management and Support Staff						-	

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.
[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4b. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Irrigation, 2010.

Constraints	Activities: Develop Irrigation Wells	Re-Lift Pumps	Pump Groundwater	Purchase Surface Water
Minimize Objective	+[a]	+	+	+
Dollar Resources	+	+	+	+
Headquarters				
Land Resources				
Close Loop				
Machinery Leasing				
Labor Resources			+	+
Groundwater Resources	+/-[b]		+	
Surface Water Resources				+
All Irrigation Water			-	-
Re-Lift Pumps		-		
Machinery Resources				
Field Work Transfers 1 - 10				
Field Work Transfers 10 to 11 Always Planting				
Field Work Transfers 11 Always Planting to 12 - 17				
Field Work Transfers 17 to 18 Always Harvesting				
Field Work Transfers 18 Always Harvesting to 19 - Close Loop				
Link Planting and Harvesting				
Transfer Harvested HES to Storage				
Transfer Harvested SG to Storage				
Purchase Transported Alternative Biomass feedstock				
Purchase Delivered Alternative Biomass feedstock				
Storage Capacity				
Transfer All Biomass feedstocks to Conversion Facility				
Required HES and SG Production				
Periodic Conversion Facility Requirements				
Restrict Capital Investments				
Overhead Management and Support Staff				

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.
[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4c. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for HES Field Operations 1 - 20 and HES Close Land Loop, 2010.

	Activities					
Constraints	HES Field Operations 1 - 10	HES Field Operations 11 - Always Planting	HES Field Operations 12 -17	HES Field Operations - 18 Always Harvesting	HES Field Operations 19 - Close Loop	HES Close Land Loop
Minimize Objective	+[a]	+	+	+	+	+
Dollar Resources	+	+	+	+	+	+
Headquarters						
Land Resources						-[b]
Close Loop	+					
Machinery Leasing						
Labor Resources	+	+			+	
Groundwater Resources						
Surface Water Resources						
All Irrigation Water		+				
Re-Lift Pumps						
Machinery Resources	+	+	+	+	+	+
Field Work Transfers 1 - 10	+/-					
Field Work Transfers 10 to 11 Always Planting		+/-				
Field Work Transfers 11 Always Planting to 12 - 17			+/-			
Field Work Transfers 17 to 18 Always Harvesting				+/-		
Field Work Transfers 18 Always Harvesting to 19 - Close Loop					+/-	+
Link Planting and Harvesting		-		+		
Transfer Harvested HES to Storage						
Transfer Harvested SG to Storage						
Purchase Transported Alternative Biomass feedstock						
Purchase Delivered Alternative Biomass feedstock						
Storage Capacity						
Transfer All Biomass Feedstocks to Conversion Facility						
Required HES and SG Production						
Periodic Conversion Facility Requirements						
Restrict Capital Investments						
Overhead Management and Support Staff						

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.

[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4d. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for SG Field Operations, and Transportation, 2010.

Constraints	Activities				
	SG Field Operations	Transport HES	Transport SG	Transport Purchased Alternative Biomass feedstock	Purchase Delivered Alternative Biomass feedstock
Minimize Objective	+[a]	+	+	+	+
Dollar Resources	+	+	+	+	+
Headquarters					
Land Resources	+/-[b]				
Close Loop					
Machinery Leasing					
Labor Resources	+	+	+	+	+
Groundwater Resources					
Surface Water Resources					
All Irrigation Water					
Re-Lift Pumps					
Machinery Resources	+	+	+	+	+
Field Work Transfers 1 - 10					
Field Work Transfers 10 to 11 Always Planting					
Field Work Transfers 11 Always Planting to 12 - 17					
Field Work Transfers 17 to 18 Always Harvesting					
Field Work Transfers 18 Always Harvesting to 19 - Close Loop					
Link Planting and Harvesting		-			
Transfer Harvested HES to Storage		+			
Transfer Harvested SG to Storage			+		
Purchase Transported Alternative Biomass feedstock				+	
Purchase Delivered Alternative Biomass feedstock					+
Storage Capacity		+	+	+	+
Transfer All Biomass feedstocks to Conversion Facility		-	-	-	-
Required HES and SG Production		+	+		
Periodic Conversion Facility Requirements					
Restrict Capital Investments					
Overhead Management and Support Staff					

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.
[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4e. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Transport SG, Purchase and Delivery of Alternative Biomass Feedstocks, Storage, and Cellulosic Plants Periodic Requirements, 2010.

Constraints	Purchase Storage	Transfer Unused Biomass feedstock	Cellulosic Plant Requirements
Minimize Objective Function	+[a]	+	+
Dollar Resources	+	+	+
Headquarters			
Land Resources	+		
Close Loop			
Machinery Leasing			
Labor Resources			
Groundwater Resources			
Surface Water Resources			
All Irrigation Water			
Re-Lift Pumps			
Machinery Resources			
Field Work Transfers 1 - 10			
Field Work Transfers 10 to 11 Always Planting			
Field Work Transfers 11 Always Planting to 12 - 17			
Field Work Transfers 17 to 18 Always Harvesting			
Field Work Transfers 18 Always Harvesting to 19 - Close Loop			
Link Planting and Harvesting			
Transfer Harvested HES to Storage			
Transfer Harvested SG to Storage			
Purchase Transported Alternative Biomass feedstock			
Purchase Delivered Alternative Biomass feedstock			
Storage Capacity	-[b]		
Transfer All Biomass feedstocks to Conversion Facility		+/-	+
Required HES and SG Production			
Periodic Conversion Facility Requirements			+
Restrict Capital Investments	+		
Overhead Management and Support Staff			

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.
[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4f. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for Transfer Unused Tractor Hours and Overhead Management, 2010.

	Activities		
Constraints	Transfer Unused 225 hp Tractor Hours to 152 hp Tractor	Transfer Unused 152 hp Tractor hours to 100 hp Tractor	Overhead Management
Minimize Objective	+[a]	+	+
Dollar Resources	+	+	+
Headquarters			
Land Resources			
Close Loop			
Machinery Leasing			
Labor Resources			
Groundwater Resources			
Surface Water Resources			
All Irrigation Water			
Re-Lift Pumps			
Machinery Resources	+/-[b]	+/-	
Field Work Transfers 1 - 10			
Field Work Transfers 10 to 11 Always Planting			
Field Work Transfers 11 Always Planting to 12 - 17			
Field Work Transfers 17 to 18 Always Harvesting			
Field Work Transfers 18 Always Harvesting to 19 - Close Loop			
Link Planting and Harvesting			
Transfer Harvested HES to Storage			
Transfer Harvested SG to Storage			
Purchase Transported Alternative Biomass feedstock			
Purchase Delivered Alternative Biomass feedstock			
Storage Capacity			
Transfer All Biomass feedstocks to Conversion Facility			
Required HES and SG Production			
Periodic Conversion Facility Requirements			
Restrict Capital Investments			
Overhead Management and Support Staff			+

[a] Inasmuch as the intent is to minimize the objective function within Sorghasaurus©, costs are represented as plus signs and income returns are represented as minus signs in the objective function row.

[b] In the resource/constraint rows (all rows of the model except the objective function row), minus signs represent a supply of the associated resource/constraint and plus signs represent a demand on the same.

Table A4g. Design of Sorghasaurus© Cost-Minimizing Linear Programming Model Framework for RHS Signs and Constraints, 2010.

Constraints	RHS Signs	Constraints
Minimize Objective Function	n/a[a]	n/a
Dollar Resources	< = >	0, us[b]
Headquarters	< =	0
Land Resources	< = >	0, us
Close Loop	=	0
Machinery Leasing	< =	us
Labor Resources	< =	0, us
Groundwater Resources	< =	0, us
Surface Water Resources	< =	0
All Irrigation Water	< =	0
Re-Lift Pumps	< =	0
Machinery Resources	< =	0
Field Work Transfers 1 - 10[c]	< =	0
Field Work Transfers 10 to 11 Always Planting	< =	0
Field Work Transfers 11 Always Planting to 12 - 17	< =	0
Field Work Transfers 17 to 18 Always Harvesting	< =	0
Field Work Transfers 18 Always Harvesting to 19 - Close Loop	< =	0
Link Planting and Harvesting	< =	0
Transfer Harvested HES to Storage	< =	0
Transfer Harvested SG to Storage	< =	0
Purchase Transported Alternative Biomass feedstock	< =	us
Purchase Delivered Alternative Biomass feedstock	< =	us
Storage Capacity	< =	0
Transfer All Biomass feedstocks to Conversion Facility	< =	0
Required HES and SG Production	< = >	us
Periodic Conversion Facility Requirements	> =	us
Restrict Capital Investments	< =	us
Overhead Management and Support Staff	< = >	us

[a] n/a: not applicable.
[b] "US" means user specified.
[c] All transfer rows are established to assure adherence to Demand of the respective factor being less than or equal to its Supply; mathematically, Demand-Supply <=0, with activities which use the factor having positive coefficients and those activities which produce the factor having negative coefficients; therefore the RHS signs for all transfer rows are configured as <=.

Table A5. Year 2 Baseline Scenario of HES and SG Annual Total Cost by Major Segment, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment [a]	Total Cost	Annual Cost per Acre of Biomass Feedstock[b]	Annual Cost per Dry Ton of Biomass Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Cost
Borrow Operating Money	$ 962,278	$ 12.99	$ 2.41	$ 0.0321	1.80%
Headquarters	988,015	13.34	2.47	0.0329	1.84%
HES Production Land	2,118,588	28.60	5.30	0.0706	3.95%
SG Land	1,537,563	20.76	3.84	0.0513	2.87%
Purchased Machinery	**8,298,523**	**112.04**	**20.75**	**0.2766**	**15.48%**
Full-Time Labor	**8,317,675**	**112.29**	**20.79**	**0.2773**	**15.52%**
Part-Time Labor	544,461	7.35	1.36	0.0181	1.02%
Irrigation	**5,506,718**	**74.35**	**13.77**	**0.1836**	**10.27%**
HES Field Operations	**11,816,294**	**159.53**	**29.54**	**0.3939**	**22.04%**
Transport HES	2,255,441	30.45	5.64	0.0752	4.21%
SG Establishment	1,694,634	22.88	4.24	0.0565	3.16%
SG Field Operations	3,462,180	46.74	8.66	0.1154	6.46%
Transport SG	353,171	4.77	0.88	0.0118	0.66%
Storage	1,869,809	25.24	4.67	0.0623	3.49%
Overhead Management	3,876,855	52.34	9.69	0.1292	7.23%
Totals	$53,602,203	$723.67	$134.01	$1.7867	100.00%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG biomass feedstock, SG land grown for insurance, and both full- and part-time labor. HES refers to High-Energy Sorghum and SG refers to Switchgrass.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.

[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

[e] The rows for those components representing more than or equal to 10 percent of the total costs arbitrarily are bolded, signifying their greater degree of magnitude.

Table A6. Summary of Year 2 Baseline Scenario for HES and SG, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item [a]	Annual Cost	Annual Cost per Acre[b]	Annual Cost per Dry Ton of Biomass feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Cost
Capital Investment	$14,919,357	$201.42	$ 37.30	$0.4973	27.83%
Operating Costs	38,682,845	522.25	96.71	1.2894	72.17%
Total Costs	$53,602,203	$723.67	$134.01	$1.7867	100.00%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG biomass feedstock, SG land grown for insurance, and both full- and part-time labor. HES refers to High-Energy Sorghum and SG refers to Switchgrass.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.
[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table A7. Summary of Year 2 Baseline Scenario Required Capital Investments for HES and SG, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item [a]	Full Capital Investment Cost	Amortized Investment Cost	Annual Cost per Acre of Biomass feedstock[b]	Annual Cost per Ton of Biomass feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Annual Capital Costs
Headquarters	$ 5,579,279	$ 988,015	$ 13.34	$ 2.47	$ 0.0329	7%
Purchased Machinery	46,913,459	8,298,523	112.04	20.75	0.2766	56%
Irrigation	24,852,075	2,068,376	27.92	5.17	0.0689	14%
SG Custom Establishment	23,036,147	1,694,634	22.88	4.24	0.0565	11%
Storage	17,868,336	1,869,809	25.24	4.67	0.0623	13%
Total	$118,249,295	$14,919,357	$201.42	$37.31	$ 0.4973	100%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG biomass feedstock, SG land grown for insurance, and both full- and part-time labor. HES refers to High-Energy Sorghum and SG refers to Switchgrass.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.

[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of feedstock (Avant 2009).

Table A8. Year 2 Baseline Scenario Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item [a]	Units	Units Required	Full Capital Investment Cost	Amortized Investment Cost	Annual Cost per Acre[b]	Annual Cost per Ton of Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Annual Costs
Headquarters								
Road Base	sq-ft	234,069	$ 107,672	$ 28,992	$ 0.39	$0.0725	$0.0010	0.19%
Office Space	sq-ft	7,407	1,111,050	195,230	2.64	0.4881	0.0065	1.31%
Pole Barns	sq-ft	87,315	1,222,410	214,797	2.90	0.5370	0.0072	1.44%
Inside Machinery Storage	sq-ft	25,922	3,110,640	546,590	7.38	1.3665	0.0182	3.66%
Headquarters Land	sq-ft	241,288	27,507	2,406	0.03	0.0060	0.0001	0.02%
Purchased Machinery								
Tractor Size 1	nbr	21	3,623,760	693,807	9.37	1.7345	0.0231	4.65%
Tractor Size 2[e]	**nbr**	**37**	**4,885,850**	**797,594**	**10.77**	**1.9940**	**0.0266**	**5.35%[e]**
Tractor Size 3[f]	nbr	0	0	0	0	0	0	0%
Planter	nbr	7	461,188	264,065	3.57	0.6602	0.0088	1.77%
Harvester	**nbr**	**13**	**4,804,974**	**1,184,676**	**15.99**	**2.9617**	**0.0395**	**7.94%**
In-Field Buggy	nbr	49	1,788,500	283,148	3.82	0.7079	0.0094	1.90%
Transport Trucks	**nbr**	**115**	**12,190,000**	**1,971,923**	**26.62**	**4.9298**	**0.0657**	**13.22%**
HES End-Dump Semi Trailers	nbr	115	5,968,500	678,032	9.15	1.6951	0.0266	4.54%
SG Flatbed Semi Trailers	nbr	20	700,000	87,254	1.18	0.2181	0.0029	0.58%
Support Vehicles	nbr	26	910,000	217,185	2.93	0.5430	0.0072	1.46%
Storage Handling	nbr	34	4,182,850	563,295	7.60	1.4082	0.0188	3.78%
Disc	nbr	8	359,970	99,563	1.34	0.2489	0.0033	0.67%
Bedder	nbr	13	258,700	27,758	0.37	0.0694	0.0009	0.19%

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Table A8. (Continued).

Capital Item	Units	Units Required	Full Capital Investment Cost	Amortized Investment Cost	Annual Cost per Acre[b]	Annual Cost per Ton of Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Annual Costs
Fertilizer Toolbar	nbr	8	$ 120,000	$ 21,373	$ 0.29	$ 0.05	0.0007	0.14%
Cultivator	nbr	3	283,500	67,084	0.91	0.17	0.0022	0.45%
Sprayer	nbr	1	226,628	39,782	0.54	0.10	0.0013	0.27%
Hay Cutter	nbr	6	695,178	163,525	2.21	0.41	0.0055	1.10%
Wheel Rake	nbr	4	86,500	25,665	0.35	0.06	0.0009	0.17%
Square Baler	nbr	8	775,752	132,474	1.79	0.33	0.0044	0.89%
Hipper	nbr	14	334,670	59,608	0.80	0.15	0.0020	0.40%
Rolling Cultivator	nbr	4	121,160	34,293	0.46	0.09	0.0011	0.23%
Land Plane	nbr	8	316,000	84,854	1.15	0.21	0.0028	0.57%
Bale Wagon	nbr	15	2,181,480	464,354	6.27	1.16	0.0155	3.11%
Hay Squeeze	nbr	12	1,638,300	337,212	4.55	0.84	0.0112	2.26%
Irrigation								
Irrigation Well Size 2	**nbr**	**78**	**20,608,575**	**1,663,447**	**22.46**	**4.16**	**0.0554**	**11.15%**
Re-Lift Pump	nbr	246	4,260,750	406,576	5.47	1.01	0.0136	2.71%
SG Custom Establishment								
SG Harvest Production	**acre**	**37,225**	**11,104,147**	**816,867**	**11.03**	**2.04**	**0.0272**	**5.48%**
SG Insurance Production	**acre**	**40,000**	**11,932,000**	**877,767**	**11.85**	**2.19**	**0.0293**	**5.88%**
Storage								
Storage Land	sq-ft	6,062,08	1,212,416	$188,793	2.55	0.47	0.0063	1.27%
Storage	**nbr**	**148**	**15,776,800**	**1,449,558**	**19.57**	**3.62**	**0.0483**	**9.72%**
Silo Cover	sq-ft	3,516,48	879,120	231.458	3.12	0.58	0.0077	1.55%
Total Cost			$118,249,295	$14,919,357	$201.42	$37.30	$0.4973	100%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.

[b] Feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.

[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of feedstock (Avant 2009).

[e] Bold rows represent cost segments that are arbitrarily defined as accounting for greater than five percent of total capital investment.

[f] Tractor size 3 machinery are only purchased when feedstock production is limited to SG; otherwise, there are sufficient Tractor Sizes 1 and 2 purchased for HES operations and available to substitute for Tractor Size 3 in the SG operations; i.e., surplus Tractor Sizes 1 and 2 hours are transferred to and substituted for Tractor Size 3 resources.

Table A9. Summary of Year 2 Baseline Scenario Annual Operating Cost for HES and SG, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item [a]	Total Annual Cost	Annual Cost per Acre[b]	Annual Cost per Ton of Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Annual Capital Costs
Borrow Operating Money	$ 962,278	$ 12.99	$ 2.41	$ 0.0321	2.49%
Land	3,656,150	49.36	9.14	0.1219	9.45%
Labor	8,862,136	119.65	22.16	0.2954	23.91%
Irrigation	3,438,341	46.42	8.60	0.1146	8.89%
HES Field Operations	11,741,985	158.53	29.35	0.3914	30.35%
SG Field Operations	3,395,417	45.84	8.49	0.1132	8.78%
Transportation	2,608,612	35.22	6.52	0.0870	6.74%
Transfer Tractor Hours[e]	141,072	1.90	0.35	0.0047	0.36%
Overhead Management	3,876,855	52.34	9.69	0.1292	10.02%
Total	$38,682,845	$522.25	$96.71	$1.2894	100.0%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor. HES refers to High-Energy Sorghum and SG refers to Switchgrass.

[b] Feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.

[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of feedstock (Avant 2009).

[e] Operating costs for Transfer Tractor Hours was determined by subtracting the operating costs per acre for Tractor Size 2 (152hp) from the operating costs per acre for Tractor Size 1 (225 hp) and the operating costs per acre for Tractor Size 3 (110hp) from the operating costs per acre for Tractor Size 2 (152hp). This method allows the excess Tractor Size 1 (225hp) hours to be transferred to field operations which require Tractor Size 2 (152Hp) and the excess Tractor Size 2 (152hp) hours to be transferred to field operations that require Tractor Size 3 (110hp) and capture the costs associated with operating a larger horse-power machine.

Table A10. Year 2 Baseline Scenario Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment [a]	Units	Units Required	Annual Operating Cost	Annual Cost per Acre[b]	Annual Cost per Ton of Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Variable Cost
Operating Funds							
Borrow Operating Money	$	n/a	$ 962,278	$ 12.99	$ 2.41	$0.0321	2.49%
Land							
HES Land[e]	**acres**	**36,845**	**2,118,588**	**28.60**	**5.30**	**0.0706**	**5.48%[e]**
SG Production Land	acres	37,225	837,563	11.31	2.09	0.0279	2.17%
SG Insurance Land	acres	40,000	700,000	9.45	1.75	0.0233	1.81%
Labor							
Hire Full-Time Labor	**persons**	**170**	**8,317,675**	**112.29**	**20.79**	**0.2773**	**21.50%**
Hire Part-Time Labor	persons	39	544,461	7.35	1.36	0.0181	1.41%
Irrigation							
Pump Groundwater	**acre-inches**	**614,199**	**3,438,341**	**46.42**	**8.60**	**0.1146**	**8.89%**
HES Field Operations							
Disc	n/a	n/a	129,441	1.75	0.32	0.0043	0.33%
Disc	n/a	n/a	129,441	1.75	0.32	0.0043	0.33%
Land Plane	n/a	n/a	216,349	2.92	0.54	0.0072	0.56%
Bed	n/a	n/a	68,448	0.92	0.17	0.0023	0.18%
Hip Beds	n/a	n/a	70,884	0.96	0.18	0.0024	0.18%
Fertilize	**n/a**	**n/a**	**6,986,051**	**94.32**	**17.47**	**0.2329**	**18.06%**
Hip Beds	n/a	n/a	70,884	0.96	0.18	0.0024	0.18%
Spray	n/a	n/a	441,244	5.96	1.10	0.0147	1.14%

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Table A10. (Continued).

Segment	Units	Units Required	Annual Operating Cost	Annual Cost per Acre[b]	Annual Cost per Ton of Feedstock[c]	Annual Cost per Gallon of Fuel[d]	% of Total Variable Cost
Condition Beds	n/a	n/a	73,209	0.99	0.18	0.0024	0.19%
Always Planting	pounds	257,915	1,469,562	19.84	3.67	0.0490	3.80%
Cultivate	n/a	n/a	81,988	1.11	0.20	0.0027	0.21%
Always Harvesting	**n/a**	**n/a**	**1,979,530**	**26.73**	**4.95**	**0.0660**	**5.12%**
Support Vehicles	n/a	n/a	24,884	0.34	0.06	0.0008	0.1%
SG Field Operations							
Grow and Harvest	**n/a**	**n/a**	**3,395,417**	**45.84**	**8.49**	**0.1132**	**8.78%**
Transportation and Storage							
Transport and Store HES	**wet tons**	**950,179**	**2,255,441**	**30.45**	**5.64**	**0.0752**	**8.83%**
Transport and Store SG	dry tons	100,000	353,171	4.77	0.88	0.0118	0.91%
Transfer Tractor Hours[f]							
Transfer Tractor Hours 225 hp to 152 hp	hours	7,408	74,309	1.00	0.19	0.0025	0.19%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,739	66,763	0.90	0.17	0.0022	0.17%
Overhead Management							
Overhead Management	**persons**	**46**	**3,876,855**	**52.34**	**9.69**	**0.1292**	**10.02%**
Total Cost			$38,682,845	$522.57	$96.71	$1.2894	100.0%

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.
[b] Feedstock refers to harvested HES and SG. Cost per acre was determined by dividing total costs by the summed total of HES and SG acres harvested, i.e., explicitly not including SG acreage grown for insurance.
[c] Cost per dry ton was determined by dividing total costs by the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of feedstock (Avant 2009).
[e] Bold rows represent cost segments that are arbitrarily defined as accounting for greater than five percent of total operating costs.
[f] Operating costs for Transfer Tractor Hours was determined by subtracting the operating costs per acre for Tractor Size 2 (152hp) from the operating costs per acre for Tractor Size 1(225 hp) and the operating costs per acre for Tractor Size 3 (110hp) from the operating costs per acre for Tractor Size 2 (152hp). This method allows the excess Tractor Size 1 (225hp) hours to be transferred to field operations which require Tractor Size 2 (152Hp) and the excess Tractor Size 2 (152hp) hours to be transferred to field operations that require Tractor Size 3 (110hp) and capture the costs associated with operating a larger horse-power machine.

Table A11. Comprehensive Logistics Cost for Year 2 Baseline Scenario, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Area [a]	Annualized Capital Investment Cost	Annual Operating Cost	Total Cost	% of Total Cost
Production	$ 5,041,739	$24,641,108	$29,682,847	55.38%
Insurance	910,396	859,812	1,770,208	3.30%
Harvesting	3,213,198	5,562,764	8,775,963	16.37%
Transportation	2,890,367	5,418,813	8,309,179	15.50%
Storage	2,863,657	2,200,348	5,064,006	9.45%
Total	$14,919,358	$38,682,845	$53,602,203	100.00%

[a] The baseline scenario year 2 includes the production of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.

Table A12. Year 2 Baseline Scenario Field Operation Working Periods for HES, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Flow of Time Period [a]	Disc	Disc	Landplane	Bed	Hip Rows	Fertilize	Hip Rows	Spray	pt[b]	Condition Beds
	Acres									
Jun 1-15										
Jun 16-30										
Jul 1-15										
Jul 16-31	13,093									
Aug 1-15		12,679								
Aug 16-31	6,110	415	5,684							
Sept 1-15	1,742	3,070	3,070							
Sept 16-30		2,487	1,987							
Oct 1-15	2,638	3,411	2,563							
Oct 16-31	2,382	208	3,964							
Nov 1-15	5,399	4,080	4,080							
Nov 16-30	5,481	1,319	4,558							
Dec 1-15		9,175	5,363	10,546						
Dec 16-31			5,575	26,298						
Jan 1-15					11,735	6,798	3,220	3,220		
Jan 16-31					25,109	10,707	6,296	6,296		
Feb 1-14						9,177	15,762	4,347	4,250	4,250
Feb 15-29						10,163		4,814	3,705	3,705
Mar 1-15							11,566	6,601	8,569	
Mar 16-31								8,988	12,305	8,569
Apr 1-15								2,578	3,687	6,824
Apr 16-30									4,329	8,016
May 1-15										
May 16-31										5,481
Total Acreage Worked	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845

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Table A12. (Continued).

Flow of Time Period	Planting	Cultivate	pt	pt	pt	pt	pt	Harvesting	pt	pt
	Acres									
Jun 1-15		8,421	8,421	8,421	8,421	31,150				
Jun 16-30		5,695	5,695	5,695	5,695	5,695				
Jul 1-15							36,845	4,614	4,614	4,614
Jul 16-31								8,480	8,480	8,480
Aug 1-15								4,987		
Aug 16-31								3,028	6,110	6,110
Sept 1-15								1,742	1,742	1,742
Sept 16-30								957		
Oct 1-15								1,681	2,638	2,638
Oct 16-31								1,906	2,382	2,382
Nov 1-15								3,970	5,399	5,399
Nov 16-30								5,481	5,481	5,481
Dec 1-15										
Dec 16-31										
Jan 1-15										
Jan 16-31										
Feb 1-14										
Feb 15-29	7,956									
Mar 1-15										
Mar 16-31	7,018	5,016	5,016	5,016	5,016					
Apr 1-15	8,374	2,486	2,486	2,486	2,486					
Apr 16-30	8,016	8,713	8,713	8,713	8,713					
May 1-15[c]										
May 16-31	5,481	6,514	6,514	6,514	6,514					
Total Acreage Worked	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845	36,845

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.

[b] "pt"denotes pass through in which no costs are incurred for the associated activities. The "pass through" activities are place holders for additional activities in other applications of Sorghasaurus©.

[c] The absence of field operations during the May 1-15 period is related to the relative number of days in this period in comparison to the previous and next period and the related economics thereof. That is, Sorghasaurus© determined the most economical scheduling of field operations to occur before and after this period, without any operations during this period, based on availability of machinery, equipment, and labor resources.

Table A13. Year 2 Baseline Scenario, HES and SG Storage Transfers, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Flow Of Time Periods	HES Harvested (dry tons) [a]	SG Harvested (dry tons)	Ending Carry Over From Previous Period (dry tons)[b,c]	Storage Losses per Period (drys tons)	Feedstock Consumed by Conversion Plant (dry tons)
Jun A[c]	0	17,481	4,652	36.35	16,427
Jun B	0	11,822	0	46.52	16,427
Jul A	20,300	0	3,873	0	16,427
Jul B	56,583	0	42,895	38.73	17,522
Aug A	40,571	0	66,610	428.95	16,427
Aug B	32,705	0	81,127	666.10	17,522
Sept A	20,993	0	84,882	811.27	16,427
Sept B	11,478	0	79,085	848.82	16,427
Oct A	21,182	0	83,048	790.85	16,427
Oct B	27,442	0	92,138	830.48	17,522
Nov A	42,877	0	117,666	921.38	16,427
Nov B	39,134	0	139,196	1,176.66	16,427
Dec A	0	1,027	122,404	1,391.96	16,427
Dec B	0	0	103,658	1,224.04	17,522
Jan A	0	0	86,194	1,036.58	16,427
Jan B	0	0	67,810	861.94	17,522
Feb A	0	0	51,800	678.10	15,332
Feb B	0	0	35,676	518.00	15,606
Mar A	0	0	18,892	356.76	16,427
Mar B	0	12,418	13,599	188.92	17,522
Apr A	0	13,163	10,199	135.99	16,427
Apr B	0	16,133	9,803	101.99	16,427
May A	0	14,477	7,754	98.03	16,427
May B	0	13,480	3,635	77.54	17,522

[a] The Year 2 Baseline Scenario includes the production, harvest, transportation, and storage of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor. HES refers to High-Energy Sorghum and SG refers to Switchgrass.

[b] The amount of feedstock carried over from the previous bi-weekly period is multiplied by 99 percent to account for feedstock degradation during storage.

[c]Not included in table 13 is recognition nor accounting for the extra three periods of "insurance" feedstocks inventory that were produced during year one of the baseline scenario.

[d] The Sorghasaurus© model is structured such that the 24-designated biweekly periods are specified June-May. However, the flexibility of the model allows for its application to varied situations in which the agronomic operations start and end during the year as appropriate.

Table A14. Example of Storage Inventory Accounting for Year 2 Baseline Scenario, July A to July B, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item [a, b]	Units	Number
Feedstock remaining at end of July A period	dry ton	3,873.00
Less: Storage transfer loss from transfer to July B	dry ton	38.73
Net transfer amount	dry ton	3,834.27
Plus: July B harvest	dry ton	56,583.00
Less: July B Conversion Facility Requirements	dry ton	17,522.00
Carryover of Feedstock to August A Period [c, d]	dry ton	42,895.27

[a] HES and SG feedstocks are commingled and assumed equivalent for biomass conversion purposes in this thesis research.
[b] The baseline scenario year 2 includes the production of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.
[c] Stated in pre-storage loss terms relative to the August a period.
[d] [c]Not included in table 14 is recognition nor accounting for the extra three periods of "insurance" feedstocks inventory that were produced during year one of the baseline scenario.

Table A15. Critical Results for Baseline Year 2 Scenario, Basis for Comparison in Subsequent Sensitivity Scenario Analyses, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Amount[a]
Production Levels	
Acres of HES	36,845
Acres of SG	37,225
Total farm acres[b]	187,760
HES Dry Ton Production	313,266
HES Wet Ton Production	950,719
SG Dry Ton Production	100,000
Average HES Dry Ton Yield per Acre	8.50
Average SG Dry Ton Yield per Acre	2.69
Total Capital Investment and Operating Costs	
Annual Cost	$53,602,203
Cost per Acre of All Feedstock Produced	723.67
Cost Per Dry Ton of Feedstock Produced	134.01
Cost per Gallon of Fuel	1.7867
Capital Investment Costs	
Total Purchase Costs	$118,249,295
Annualized Investment Costs	14,919,357
Percent of All Costs	27.8%
Cost per Acre of All Feedstock Produced	201.42
Cost Per Dry Ton of Feedstock Produced	37.30
Cost per Gallon of Fuel	0.4973
Annual Operating Costs	
Total Annual Operating Costs	$38,682,845
Percent of All Costs	72.2%
Cost per Acre of All Feedstock Produced	522.25
Cost Per Dry Ton of Feedstock Produced	96.71
Cost per Gallon of Fuel	1.2894

[a] The baseline scenario year 2 includes the production of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.

[b] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table A16. Summary of Estimated Costs and Returns per Acre for HES and SG Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
Income							
HES Feedstock -- harvested dry ton per acre on 0.4974 acre	ton	---	4.05	---	300,000		
SG Feedstock -- harvested dry ton on 0.5026 acre	ton	---	1.35	---	100,000		
Total Income							

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Table A16, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
DIRECT EXPENSES							
Lease Land							
HES Production Land	acre	57.50	0.4974	$ 28.60	$ 2,118,439	$ 5.30	3.95%
SG Production Land	acre	22.50	0.5026	11.31	837,621	2.09	1.56%
SG Insurance Land	acre	17.50	0.5400	9.45	699,962	1.75	1.31%
SEED							0.00%
HES Seed	lb	5.00	3.4820	17.41	1,289,559	3.22	2.41%
FERTILIZERS							0.00%
HES	lb	0.39	238.7687	93.12	6,897,383	17.24	12.87%
SG	lb	0.39	60.3078	23.52	1,742,130	4.36	3.25%
HERBICIDES							0.00%
HES-Bicep	pt	5.63	0.9948	5.60	414,846	1.04	0.77%
SG-2,4-D Amine	pt	1.88	2.0103	3.78	279,937	0.70	0.52%
TWINE							
SG	acre	6.62	0.5026	3.33	246,447	0.62	0.46%
IRRIGATION	ac-in	2.78	16.6700	46.34	3,432,596	8.58	6.40%
OPERATOR LABOR							
full-time	hour	27.07	4.1488	112.31	8,318,655	20.80	15.52%
part-time	hour	13.49	0.5448	7.35	544,367	1.36	1.02%
DIESEL FUEL	gal	2.05	29.2001	59.86	4,433,841	11.08	8.27%
REPAIR & MAINTENANCE	acre	34.97	1.0000	34.97	2,590,228	6.48	4.83%
INTEREST ON OPERATING	acre	12.99	1.0000	12.99	962,169	2.41	1.79%
TOTAL DIRECT EXPENSES				**$ 469.94**	**$ 34,808,178**	**$ 87.02**	**64.94%**

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Table A16, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
FIXED EXPENSES							
Depreciation and Interest							
Implements	acre	13.78	1.0000	$ 13.78	$ 1,020,685	$ 2.55	1.90%
Tractors	acre	18.30	1.0000	18.30	1,355,481	3.39	2.53%
Self-Propelled	acre	36.93	1.0000	36.93	2,735,405	6.84	5.10%
Transportation	acre	24.05	1.0000	24.05	1,781,384	4.45	3.32%
Irrigation	acre	24.56	1.0000	24.56	1,819,159	4.55	3.39%
Storage	acre	19.06	1.0000	19.06	1,411,774	3.53	2.63%
Headquarters	acre	11.41	1.0000	11.41	845,139	2.11	1.58%
Other Capital Ownership Costs							
Property Taxes	acre	6.21	1.0000	6.21	459,975	1.15	0.86%
Repair and Maintenance	acre	10.50	1.0000	10.50	777,735	1.94	1.45%
Insurance	acre	13.74	1.0000	13.74	1,017,722	2.54	1.90%
Other Fixed							
SG Custom	acre	22.88	1.0000	22.88	1,694,722	4.24	3.16%
TOTAL FIXED EXPENSES				**$ 201.42**	**$ 14,919,179**	**$ 37.30**	**27.83%**
TOTAL SPECIFIED EXPENSES				**$ 671.36**	**$ 49,727,357**	**$ 124.32**	**92.77%**
MANAGEMENT CHARGE	acre	52.34	1	**$ 52.34**	**$ 3,876,824**	**$ 9.69**	**7.23%**
TOTAL COSTS				**$ 723.70**	**$ 53,604,181**	**$ 134.02**	**100.00%**
Breakeven Costs Per Dry Ton (accounting for storage losses)				**$ 134.02**	**$ 134.01**		

Table A17. Summary of Estimated Costs and Returns per Acre for HES Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
Income							
HES Feedstock -- harvested dry ton per acre on 1 acre	ton	---	7.92	---	400,000		
Total Income							

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Table A17, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
DIRECT EXPENSES							
Lease Land							
HES Production Land	acre	57.50	1.0000	$57.50	$ 2,904,613	$ 7.26	4.56%
SG Insurance Land	acre	17.50	0.7918	13.86	700,000	1.75	1.10%
SEED							
HES Seed	lb	5.00	7.0000	35.00	1,768,025	4.42	2.78%
FERTILIZERS							
HES	lb	0.39	480.0000	187.20	9,456,408	23.64	14.85%
HERBICIDES							
HES-Bicep	pt	5.64	2.0000	11.28	569,809	1.42	0.89%
TWINE							
SG	acre	6.62	0.0000	0.00	0		0.00%
IRRIGATION	ac-in	5.60	16.6700	93.32	4,714,071	11.79	7.40%
OPERATOR LABOR							
full-time	hour	35.74	6.7753	242.14	12,231,875	30.58	19.21%
part-time	hour	13.49	0.7851	10.59	535,055	1.34	0.84%
DIESEL FUEL	gal	2.05	45.9561	94.21	4,759,018	11.90	7.47%
REPAIR & MAINTENANCE	acre	75.82	1.0000	52.87	2,670,728	6.68	4.19%
INTEREST ON OPERATING	acre	22.67	1.0000	22.67	1,145,175	2.86	1.80%
TOTAL DIRECT EXPENSES				**$ 820.64**	**$ 41,454,777**	**103.64**	**65.11%**

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Table A17, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
FIXED EXPENSES							
Depreciation and Interest							
Implements	acre	22.87	1.0000	$ 22.87	$ 1,694,057	$ 2.89	1.81%
Tractors	acre	37.52	1.0000	37.52	2,779,382	4.74	2.98%
Self-Propelled	acre	51.51	1.0000	51.51	3,815,448	6.51	4.09%
Transportation	acre	46.51	1.0000	46.51	3,444,863	5.87	3.69%
Irrigation	acre	47.17	1.0000	47.17	3,493,707	5.96	3.74%
Storage	acre	62.55	1.0000	62.55	4,632,747	7.90	4.96%
Headquarters	acre	18.29	1.0000	18.29	1,354,494	2.31	1.45%
Other Capital Ownership Costs							
Property Taxes	acre	1.02	1.0000	1.02	75,551	0.13	0.08%
Repair and Maintenance	acre	18.92	1.0000	18.92	1,401,496	2.39	1.50%
Insurance	acre	25.74	1.0000	25.74	1,906,562	3.25	2.04%
Other Fixed							
SG Custom	acre	17.38	1.0000	17.38	1,287,337	2.19	1.38%
TOTAL FIXED EXPENSES				**$ 349.48**	**$ 25,885,644**	**$ 44.13**	**27.73%**
TOTAL SPECIFIED EXPENSES				**$ 1,170.12**	**$ 59,108,528**	**$ 147.77**	**92.83%**
MANAGEMENT CHARGE	acre	90.32	1	**$ 90.32**	**$ 4,562,515**	**$ 11.41**	**7.17%**
TOTAL COSTS				**$ 1,260.44**	**$ 63,671,042**	**$ 159.18**	**100.00%**
Breakeven Costs Per Dry Ton (accounting for storage losses)				**$ 159.18**	**$ 159.18**		

Table A18. Summary of Estimated Costs and Returns per Acre for SG Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
Income							
SG Feedstock -- harvested dry ton on 1 acre	ton	---	2.74	---	400,000		
Total Income							

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Table A18, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
DIRECT EXPENSES							
Lease Land							
SG Production Land	acre	22.50	1.0000	$ 22.50	$ 3,279,218	$ 8.20	9.29%
SG Insurance Land	acre	17.50	0.2745	4.80	700,000	1.75	1.98%
SEED							
HES Seed	lb	5.00	0.0000	0.00	-	-	0.00%
FERTILIZERS							
SG	lb	0.39	120.0000	46.80	6,820,772	17.05	19.33%
Custom Operations							
Fertilizer	acre	5.50	1.0000	5.50	801,587	2.00	2.27%
HERBICIDES							
SG-2,4-D Amine	pt	1.88	2.5000	4.70	684,992		0.00%
TWINE							
SG	acre	6.62	1.0000	6.62	964,819	2.41	2.73%
IRRIGATION	ac-in	5.60	0.0000	0.00	-		0.00%
OPERATOR LABOR							
full-time	hour	15.74	1.7065	26.86	3,914,200	9.79	11.09%
part-time	hour	13.49	0.1776	2.40	349,253		0.00%
DIESEL FUEL	gal	2.05	10.8782	22.30	3,250,119	8.13	9.21%
REPAIR & MAINTENANCE	acre	13.44	1.0000	13.44	1,959,196	4.90	5.55%
Miscellaneous	acre	2.00	1.0000	2.00	291,486	0.73	0.83%
INTEREST ON OPERATING	acre	4.58	1.0000	4.58	$ 667,288	1.67	1.89%
TOTAL DIRECT EXPENSES				**$ 162.50**	**$ 23,682,929**	**59.21**	**67.12%**

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Table A18, continued.

Item	Unit	Price	Quantity	Amount Per Average Acre	Farm Total	Per Dry Ton Cost	% of Total Cost
FIXED EXPENSES							
Depreciation and Interest							
Implements	acre	1.49	1.0000	$ 1.49	$ 216,515	$ 0.54	0.61%
Tractors	acre	1.80	1.0000	1.80	262,452	0.66	0.74%
Self-Propelled	acre	11.08	1.0000	11.08	1,614,946	4.04	4.58%
Transportation	acre	3.27	1.0000	3.27	475,994	1.19	1.35%
Irrigation	acre	0.00	1.0000	-	-	-	0.00%
Storage	acre	4.78	1.0000	4.78	696,580	1.74	1.97%
Headquarters	acre	3.82	1.0000	3.82	556,773	1.39	1.58%
Other Capital Ownership Costs							
Property Taxes	acre	0.08	1.0000	0.08	11,930	0.03	0.03%
Repair and Maintenance	acre	1.35	1.0000	1.35	196,500	0.49	0.56%
Insurance	acre	2.38	1.0000	2.38	347,420	0.87	0.98%
Other Fixed							
SG Custom	acre	27.97	1.0000	27.97	2,071,506	10.19	11.55%
TOTAL FIXED EXPENSES				**$ 58.01**	**$ 4,297,071**	**$ 21.14**	**23.96%**
TOTAL SPECIFIED EXPENSES				**$ 220.51**	**$ 32,138,013**	**$ 80.35**	**91.08%**
MANAGEMENT CHARGE	acre	21.6	1	**$ 21.60**	**$ 3,148,049**	**$ 7.87**	**8.92%**
TOTAL COSTS				**$ 242.11**	**$ 35,286,061**	**$ 88.22**	**100.00%**
Breakeven Costs Per Dry Ton (accounting for storage losses)				**$ 88.22**	**$ 88.22**		

Table A19. Select Critical Results for Baseline and Sensitivity Scenarios 1: Production For Insurance, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Production for Insurance Sensitivity Scenario 1A Results	Sensitivity Scenario 1B Results
Description of Scenario	Baseline	Three Extra Periods of Biorefinery Feedstock Requirements	Excess SG Production Equivalent to 25% of Biorefinery Feedstock Requirements
		$ million	
Total Capital Investment Purchase Costs	$118.2	$136.1	$106.3
Annualized Capital Investment Purchase Costs	14.9	17.2	14.0
Total Annual Operating Costs	38.7	44.9	38.0
Annual Capital Investment and Operating Costs	53.6	62.2	52.0
		$	
Cost per Acre of All Feedstock Produced	$723.67	$762.66	702.13
Cost per Dry Ton of All Feedstock Produced	134.01	138.42	130.02
Cost per Gallon of Fuel	1.7867	1.8456	1.7336
		%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	116.0	97.0

Table A20. Select Critical Results for Baseline and Sensitivity Scenarios 2: HES Yields, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

		HES Yields			
Item	Year 2 Baseline Results	Sensitivity Scenario 2A Results	Sensitivity Scenario 2B Results	Sensitivity Scenario 2C Results	Sensitivity Scenario 2D Results
Description of Scenario	Baseline	HES Yield @ 8 tons/ac and no Irrigation	HES Yield @ 12 tons/ac and no Irrigation	HES Yield @ 18 tons/ac	HES Yield @ 25 tons/ac
			$ million		
Total Capital Investment Purchase Costs	$118.2	$97.9	$90.7	$104.0	$96.6
Annualized Capital Investment Purchase Costs	14.9	13.9	12.3	12.9	11.7
Total Annual Operating Costs	38.7	39.3	35.2	35.0	32.9
Annual Capital Investment and Operating Costs	53.6	53.1	47.5	47.9	44.6
Cost per Acre of All Feedstock Produced	$723.67	$565.02	$625.88	$755.34	$794.87
Cost per Dry Ton of All Feedstock Produced	134.01	132.87	118.83	119.62	111.54
Cost per Gallon of Fuel	1.7867	1.7716	1.5844	1.5949	1.4872
			%		
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	99.1	88.7	89.3	83.2

Table A21. Select Critical Results for Baseline and Sensitivity Scenarios 3: SG Yields, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	SG Yields Sensitivity Scenario 3A Results	SG Yields Sensitivity Scenario 3B Results
Description of Scenario	Baseline	SG @ 2 tons/ac	SG @ 6 tons/ac
		$ million	
Total Capital Investment Purchase Costs	$118.2	$130.5	$105.2
Annualized Capital Investment Purchase Costs	14.9	16.0	13.7
Total Annual Operating Costs	38.7	40.3	37.0
Annual Capital Investment and Operating Costs	53.6	56.3	50.7
		$	
Cost per Acre of All Feedstock Produced	$723.67	$604.41	$911.58
Cost per Dry Ton of All Feedstock Produced	134.01	140.65	126.81
Cost per Gallon of Fuel	1.7867	1.8753	1.6908
		%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	105.0	94.6

Table A22. Select Critical Results for Baseline and Sensitivity Scenarios 4: Monoculture, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Monoculture: Sensitivity Scenario 4A Results	Monoculture: Sensitivity Scenario 4B Results
Description of Scenario	Baseline	Only HES for Principal Supply, Plus 25% SG for Insurance	Only SG for Principal Supply, Plus 25% SG for Insurance
		$ million	
Total Capital Investment Purchase Costs	$118.2	$137.7	$81.7
Annualized Capital Investment Purchase Costs	14.9	17.7	8.5
Total Annual Operating Costs	38.7	46.0	26.8
Annual Capital Investment and Operating Costs	53.6	63.7	35.3
		$	
Cost per Acre of All Feedstock Produced	$723.67	$1,1260.61	$242.10
Cost per Dry Ton of All Feedstock Produced	134.01	159.20	88.21
Cost per Gallon of Fuel	1.7867	2.1227	1.1761
		%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	118.8	65.8

Table A23. Select Critical Results for Baseline and Sensitivity Scenarios 5: Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Costs: Sensitivity Scenario 5A Results	Sensitivity Scenario 5B Results	Sensitivity Scenario 5C Results	Sensitivity Scenario 5D Results
Description of Scenario	Baseline	Capital Costs are Reduced 15%	Capital Costs are Increased 15%	Operating Costs are Reduced 15%	Operating Costs are Increased 15%
			$ million		
Total Capital Investment Purchase Costs	$118.2	$101.2	$135.7	$123.4	$118.3
Annualized Capital Investment Purchase Costs	14.9	12.8	17.1	15.4	15.0
Total Annual Operating Costs	38.7	38.6	38.7	32.9	44.4
Annual Capital Investment and Operating Costs	53.6	51.3	55.8	48.3	59.3
			$		
Cost per Acre of All Feedstock Produced	$723.67	$695.17	$753.69	$664.38	$800.26
Cost per Dry Ton of All Feedstock Produced	134.01	128.37	139.56	120.68	148.17
Cost per Gallon of Fuel	1.7867	1.7116	1.8608	1.6091	1.9757
			%		
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	95.8	104.1	90.1	110.6

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Table A23, Continued.

Item	Sensitivity Scenario 5E Results	Sensitivity Scenario 5F Results	Sensitivity Scenario 5G Results	Sensitivity Scenario 5H Results
	Cost, continued			
Description of Sensitivity Scenario	Discount Rate is Reduced 1%	Consider Only Farm Gate Costs	Consider Only Just-In-Time Deliveries	Consider Just-In-Time Deliveries with Adjusted Trafficable Days
	$ million			
Total Capital Investment Purchase Costs	$118.0	$73.3	$122.9	$102.6
Annualized Capital Investment Purchase Costs	14.2	9.3	16.1	12.7
Total Annual Operating Costs	38.7	25.5	39.9	39.9
Annual Capital Investment and Operating Costs	52.9	34.8	56.0	52.6
	$			
Cost per Acre of All Feedstock Produced	$714.74	$518.36	$513.97	$482.72
Cost per Dry Ton of All Feedstock Produced	132.31	86.80	140.12	131.46
Cost per Gallon of Fuel	1.7641	1.1573	1.8683	1.7528
	%			
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	98.7	64.8	104.6	98.1

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Table A23, Continued.

Item	Costs, continued			
	Sensitivity Scenario 5I Results	**Sensitivity Scenario 5J Results**	**Sensitivity Scenario 5K Results**	**Sensitivity Scenario 5L Results**
Description of Scenario	No Full-Time Labor (only part-time)	Lease all Transportation (versus purchased)	Periodic Storage Deterioration Increased to 5%	Periodic Storage Deterioration Changed to 0.2%
	$ million			
Total Capital Investment Purchase Costs	$129.0	$98.6	$137.1	$112.8
Annualized Capital Investment Purchase Costs	16.3	12.0	17.7	13.9
Total Annual Operating Costs	31.5	39.9	44.7	37.9
Annual Capital Investment and Operating Costs	47.8	51.9	62.4	51.8
	$			
Cost per Acre of All Feedstock Produced	$708.21	$709.33	$786.53	$693.52
Cost per Dry Ton of All Feedstock Produced	119.48	128.71	155.88	129.51
Cost per Gallon of Fuel	1.5931	1.7161	2.0784	1.7268
	%			
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	89.2	96.0	116.3	96.6

Table A24. Select Critical Results for Baseline and Sensitivity Scenarios 6: Machinery, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Machinery Sensitivity 6A Results	Machinery Sensitivity Scenario 6B Results	Machinery Sensitivity Scenario 6C Results	Machinery Sensitivity Scenario 6D Results
Description of Scenario	Baseline	Trafficable Days at 50%	Trafficable Days at 90%	Only SG Grown with Trafficable Days at 90%	Trafficable Days Relaxed (x10)
			$ million		
Total Capital Investment Purchase Costs	$118.2	$98.6	$153.0	$96.8	$72.1
Annualized Capital Investment Purchase Costs	14.9	11.7	21.0	11.1	7.0
Total Annual Operating Costs	38.7	34.0	46.8	29.9	37.9
Annual Capital Investment and Operating Costs	53.6	45.7	67.7	41.0	44.9
			$		
Cost per Acre of All Feedstock Produced	$723.67	$653.83	$846.60	$281.41	$620.62
Cost per Dry Ton of All Feedstock Produced	134.01	114.24	169.36	102.56	112.35
Cost per Gallon of Fuel	1.7867	1.5232	2.2581	1.3675	1.4980
			%		
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	85.2	126.4	76.5	83.8

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Table A24, Continued.

Item	Sensitivity Scenario 6E Results	Sensitivity Scenario 6F Results	Sensitivity Scenario 6G Results
	Machinery, continued		
Description of Scenario	Economics of Farm Size, with no SG and no Insurance	Maximum HES Harvest Moisture set at 25%	Increase Transportation Capacity 20%
		$ million	
Total Capital Investment Purchase Costs	$7.6	$104.4	$113.5
Annualized Capital Investment Purchase Costs	1.1	12.8	14.2
Total Annual Operating Costs	4.6	33.6	37.7
Annual Capital Investment and Operating Costs	5.6	46.4	51.9
		$	
Cost per Acre of All Feedstock Produced	$2,252.70	$644.83	$699.22
Cost per Dry Ton of All Feedstock Produced	261.52	116.03	129.63
Cost per Gallon of Fuel	3.4869	1.5471	1.7284
		%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	195.1	86.6	96.7

Table A25. Select Critical Results for Baseline and Sensitivity Scenarios 7: Moderate Aggregate, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

		Moderate Aggregate		
Item	Year 2 Baseline Results	Sensitivity Scenario 7A Results	Sensitivity Scenario 7B Results	Sensitivity Scenario 7C Results
Description of Scenario	Baseline	10 Dry Ton HES Yields with No Irrigation, Capital Costs Reduced 15%, and Trafficable Days Are Set at 50%	12 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15%, and Trafficable Days at 50%	18 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15%, and Trafficable Days at 50%
		$ million		
Total Capital Investment Purchase Costs	$118.2	$66.3	$84.7	$78.0
Annualized Capital Investment Purchase Costs	14.9	8.6	10.1	9.1
Total Annual Operating Costs	38.7	31.8	33.8	30.3
Annual Capital Investment and Operating Costs	53.6	40.5	43.9	39.4
		$		
Cost per Acre of All Feedstock Produced	$723.67	$526.99	$636.29	$669.32
Cost per Dry Ton of All Feedstock Produced	134.01	101.18	109.79	98.57
Cost per Gallon of Fuel	1.7867	1.3491	1.4639	1.3143
		%		
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100	75.5	81.9	73.6

Table A26. Select Critical Results for Baseline and Sensitivity Scenarios 8: Substantial Aggregate, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Substantial Aggregate Sensitivity Scenario 8A Results	Substantial Aggregate Sensitivity Scenario 8B Results	Substantial Aggregate Sensitivity Scenario 8C Results
Description of Scenario	Baseline	10 Dry Ton HES Yields with no Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%	12 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%	18 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%
			$ million	
Total Capital Investment Purchase Costs	$118.2	$64.7	$82.8	$73.7
Annualized Capital Investment Purchase Costs	14.9	8.4	9.8	8.6
Total Annual Operating Costs	38.7	26.4	28.1	25.3
Annual Capital Investment and Operating Costs	53.6	34.7	37.8	33.9
			$	
Cost per Acre of All Feedstock Produced	$723.67	$455.21	$549.05	$570.25
Cost per Dry Ton of All Feedstock Produced	134.01	86.82	94.56	84.75
Cost per Gallon of Fuel	1.7867	1.1576	1.2608	1.1300
			%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	64.8	70.6	63.2

Table A27 . Select Critical Results for Baseline and Sensitivity Scenarios 9: Substantial Aggregate, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Substantial Aggregate: Sensitivity Scenario 9A Results	Substantial Aggregate: Sensitivity Scenario 9B Results	Substantial Aggregate: Sensitivity Scenario 9C Results
Description of Scenario	Baseline	HES rotation acreage sub-leasing costs increased to evaluate prospects of greater returns during non-HES years	Irrigation wells are owned, but not operated	SG harvesting is prohibited during April and May
		$ million		
Total Capital Investment Purchase Costs	$118.2	$116.7	$116.7	$119.3
Annualized Capital Investment Purchase Costs	14.9	14.6	15.6	15.0
Total Annual Operating Costs	38.7	35.1	35.3	39.3
Annual Capital Investment and Operating Costs	53.6	49.7	50.0	54.3
		$		
Cost per Acre of All Feedstock Produced	723.67	$650.15	$653.61	$712.08
Cost per Dry Ton of All Feedstock Produced	134.01	124.26	124.92	135.83
Cost per Gallon of Fuel	1.7867	1.6568	1.6656	1.8111
		%		
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	100.0	92.7	93.2	101.4

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Table A27. Continued.

Item	Substantial Aggregate Sensitivity Scenario 9A Results	Sensitivity Scenario 9D Results
Description of Scenario	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Year 2 Baseline Scenario	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Economies of Size Scenario 6E
	$ million	
Total Capital Investment Purchase Costs	$116.69	$6.9
Annualized Capital Investment Purchase Costs	14.8	0.9
Total Annual Operating Costs	38.7	4.2
Annual Capital Investment and Operating Costs	53.5	5.1
	$	
Cost per Acre of All Feedstock Produced	$722.21	$2,057.29
Cost per Dry Ton of All Feedstock Produced	133.73	236.71
Cost per Gallon of Fuel	1.7831	3.1468
	%	
Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost	99.8	176.1/90.2[a]

[a] The 176.1 percent value refers to the comparison with the Year 2 Baseline Scenario results for the CBFFE when integer programming constraints are effect. The 90.2 percent value result is in comparison to the scenario 6E results in which a similar size farm to that considered in scenario 9D was evaluated (i.e., a 2,500 acre farm), with the noted integer programming constraints in effect in scenario 6E and not in scenario 9D.

Table A28. Select Critical Results for Baseline and All Sensitivity Scenarios, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Scenario	Description of Scenario	Cost per Dry Ton of All Feedstock Produced	Cost per Gallon of Fuel	Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost
Baseline Scenario		134.01	1.7867	100.0
Scenario 1A	Three Extra Periods of Biorefinery Feedstock Requirements	138.43	2.0731	103.3
Scenario 1B	Excess SG Production Equivalent to 25% of Biorefinery Feedstock Requirements	130.02	1.7336	97.0
Scenario 2A	HES Yield @ 8 tons/ac and no Irrigation	131.23	1.7497	97.9
Scenario 2B	HES Yield @ 12 tons/ac and no Irrigation	118.33	1.5844	97.9
Scenario 2C	HES Yield @ 18 tons/ac	117.95	1.5727	88.0
Scenario 2D	HES Yield @ 25 tons/ac	111.54	1.4872	83.2
Scenario 3A	SG @ 2 tons/ac	140.65	1.8754	105.0
Scenario 3B	SG @ 6 tons/ac	126.81	1.6907	94.6
Scenario 4A	Only HES for Principal Supply, Plus 25% SG for Insurance	159.20	2.1227	118.8
Scenario 4B	Only SG for Principal Supply, Plus 25% SG for Insurance	88.21	1.1761	65.8
Scenario 5A	Capital Costs are Reduced 15%	128.37	1.7116	95.8
Scenario 5B	Capital Costs are Increased 15%	139.56	1.8609	104.1
Scenario 5C	Operating Costs are Reduced 15%	120.68	1.6090	90.1
Scenario 5D	Operating Costs are Increased 15%	146.29	1.9505	109.2
Scenario 5E	Discount Rate is Reduced 1%	132.31	1.7641	98.7
Scenario 5F	Consider Only Farm Gate Costs	86.80	1.1573	64.8
Scenario 5G	Consider Only Just-In-Time Deliveries	140.12	1.8683	104.6
Scenario 5H	Just-in-Time Deliveries with Adjusted Trafficable Days	131.46	1.7528	98.1
Scenario 5I	No Full-Time Labor (only part-time)	119.48	1.5931	89.2
Scenario 5J	Lease all Transportation (versus purchased)	129.71	1.7294	96.8
Scenario 5K	Periodic Storage Deterioration Increased to 5.0%	155.88	2.0784	116.3
Scenario 5L	Periodic Storage Deterioration Decreased to 0.2%	129.50	1.7268	96.6

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Table A28, continued.

Scenario	Description of Scenario	Cost per Dry Ton of All Feedstock Produced	Cost per Gallon of Fuel	Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost
Scenario 6A	Trafficable Days at 50%	$114.24	$1.5231	85.2
Scenario 6B	Trafficable Days at 90%	169.36	2.2582	126.4
Scenario 6C	Only SG Grown with Trafficable Days at 90%	102.56	1.3675	76.5
Scenario 6D	Trafficable Days Relaxed (x10)	112.35	1.4980	83.8
Scenario 6E	Economics of Farm Size, with no SG and no Insurance	261.52	3.4870	195.1
Scenario 6F	Maximum HES Harvest Moisture set at 25%	116.03	1.5471	86.6
Scenario 6G	Increase Transportation Capacity 20%	129.63	1.7284	96.7
Scenario 7A	10 Dry Ton HES Yields with no Irrigation, Capital Costs Reduced 15%, and Trafficable Days Set at 50%	101.18	1.3491	75.5
Scenario 7B	12 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15%, and Trafficable Days Set at 50%	109.29	1.4571	81.6
Scenario 7C	18 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15% using only Part-Time Labor, and Trafficable Days Set at 50%	98.57	1.3143	73.5
Scenario 8A	10 Dry Ton HES Yields with no Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%	86.82	1.1576	64.8
Scenario 8B	12 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%	94.56	1.2608	70.6
Scenario 8C	18 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15%, Trafficable Days Set at 50%, and Transportation Capacity Increased 20%	84.75	1.1300	63.2

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Table A28, continued.

Scenario	Description of Scenario	Cost per Dry Ton of All Feedstock Produced	Cost per Gallon of Fuel	Cost per Dry Ton of All Feedstock Produced as a Percentage of the Baseline Cost
Scenario 9A	HES rotation acreage sub-leasing costs increased to evaluate prospects of greater returns during non-HES years	$124.26	$1.6568	92.7
Scenario 9B	Irrigation wells are owned, but not operated	124.92	1.6656	93.2
Scenario 9C	SG harvesting is prohibited during April and May	135.83	1.8111	101.4
Scenario 9D	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Year 2 Baseline Scenario	133.73	1.7831	99.8
Scenario 9E	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Economies of Size Scenario 6E	236.71	3.1468	176.1/90.2[a]

[a] The 176.1 percent value refers to the comparison with the Year 2 Baseline Scenario results for the CBFFE when integer programming constraints are effect. The 90.2 percent value result is in comparison to the scenario 6E results in which a similar size farm to that considered in scenario 9D was evaluated (i.e., a 2,500 acre farm), with the noted integer programming constraints in effect in scenario 6E and not in scenario 9D.

Table A29. Comparison of Comprehensive Logistics Costs for Year 2 Baseline Scenario versus Lowest (Scenario 8C) and Highest (Scenario 6E) Costing ($ per Dry Ton of Feedstock) of the Sensitivity Scenarios, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Area	Annualized Capital Investment Cost	Annual Operating Cost	Total Cost	% of Total Cost
	Baseline Scenario, Year 2[a]			
Production	$ 5,041,739	$24,641,108	$29,682,847	55.38%
Insurance	910,396	859,812	1,770,208	3.30%
Harvesting	3,213,198	5,562,764	8,775,963	16.37%
Transportation	2,890,367	5,418,813	8,309,179	15.50%
Storage	2,863,657	2,200,348	5,064,006	9.45%
Total	$14,919,358	$38,682,845	$53,602,203	100.00%
	Sensitivity Scenario 8C[b]			
Production	$2,571,355	$15,823,471	$18,394,826	54.26%
Insurance	24,098	1,477,414	1,501,512	4.43%
Harvesting	1,631,714	3,685,242	5,316,956	15.68%
Transportation	1,352,352	3,405,733	4,758,085	14.04%
Storage	2,225,931	1,701,961	3,927,891	11.59%
Total	$7,805,450	$26,093,820	$33,899,270	100.00%
	Sensitivity Scenario 6E[b]			
Production	$768,350	$2,311,807	$3,080,157	54.78%
Insurance	0.00	0.00	0.00	0.00%
Harvesting	384,037	493,590	877,626	15.61%
Transportation	494,620	494,539	989,160	17.59%
Storage	486,346	189,460	675,807	12.02%
Total	$2,133,353	$3,489,396	$5,622,749	100.00%

[a] The baseline scenario year 2 includes the production of only HES and SG feedstock, SG land grown for insurance, and both full- and part-time labor.

[b] Scenario 8C is the same as the Year 2 Baseline Scenario except for 18 dry ton hes yields with irrigation, both capital and operating costs reduced 15%, trafficable days set at 50%, and transportation capacity increased 20%.

[c] Scenario 6E is the same as the Year 2 Baseline Scenario except for consideration of economics of farm size, with single, 2,500 acre farming units with no SG and no insurance production.

Table A30. Regional Economic Multipliers for HES and Cow/Calf Enterprise for Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria Counties, 2010.

Expense Item	Implan Sector[a]	Economic Output	Value Added	Direct Employment[b]	Indirect & Induced Employment[b]
Road Base	36	1.980	0.975	6.825	5.872
Pole Barns, Inside Barns, and Offices	36	1.980	0.975	6.825	5.872
Purchase Land	360	1.406	1.043	5.301	2.738
Machinery and Equipment[c]	319	1.694	1.070	4.365	4.812
Drilling	33	1.658	1.133	2.084	4.446
Pump and Gearhead	323	1.170	1.096	10.122	4.835
Storage Bunkers	163	1.776	0.857	5.450	4.600
Cash Lease Land	360	1.406	1.043	5.301	2.738
All Fuel	326	1.594	1.053	10.563	4.038
All Repair and Maintenance	417	1.555	0.973	5.088	3.610
Poly Pipe	323	1.170	1.096	10.122	4.835
Fertilizer, Herbicide, and Seed	19	2.014	1.330	35.376	6.397
Full-Time Labor and Overhead Management[d]					
Silo Covers	36	1.544	1.039	3.451	3.676
Custom Farming Operations	417	1.980	0.975	6.825	5.872
Financial Services	354	1.555	0.973	5.088	3.610
Cow/Calf Enterprise	11	1.781	0.579	20.733	7.142

Source: McCorkle (2010).

[a] IMPLAN sector definitions are:

Road Base	35 - Construction of other new nonresidential structures
Pole Barns, Inside Barns, and Offices	36 - Construction of other new nonresidential structures
Purchase Land	360 - Real Estate Establishments
Machinery and Equipment	319 - Wholesale Trade Business
Drilling	33 - Water, sewage, and other treatment and delivery systems
Pump and Gearhead	323 - Building Material and Garden Supply
Storage Bunkers	163 - Other Concrete product manufacturing
Cash Lease Land	360 - Real Estate Establishments
All Fuel	326 - Retail Gasoline Stations
All Repair and Maintenance	417 - Commercial and industrial machinery and equipment repair and maintenance
Poly Pipe	323 - Building Material and Garden Supply
Fertilizer, Herbicide, Seed, and Baling Wire	19 - Support activities for agriculture and forestry
Full-Time Labor and Overhead Management	instead of sector definition, used Household Income Expenditures Pattern
Banking	354 - Monetary authorities and depository credit intermediation activities
Silo Covers	36 - Construction of other new nonresidential structures
Custom SG Establishment	417 - Commercial and industrial machinery and equipment repair and maintenance

[b] Employment multipliers are per $1 million of output.

[c] Machinery purchases are assumed handled through local dealer(s) and thus credit is given locally to full magnitude of sales/purchases.

[d] Multipliers for full-time labor and overhead management were not identified.

Table 31. Economic Impact of Producing HES in Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria Counties for the Startup Year, 2010.

Expense Items	Direct Cost ($)	Economic Output ($)	Value Added ($)	Direct Employment	Indirect and Induced Employment	Total Employment
HES Capital Investments						
Road Base	$107,672	$213,190	$104,980	0.7	0.6	1.4
Pole Barns, Inside Barns, and Offices	5,444,100	10,779,318	5,307,998	37.2	32.0	69.1
Purchase Land	1,239,923	1,743,332	1,293,240	6.6	3.4	10.0
Machinery and Equipment[a]	46,913,459	79,471,400	50,197,401	204.8	225.7	430.5
Irrigation well Drilling	16,146,000	26,770,068	18,293,418	33.6	71.8	105.4
Pump and Gearhead	8,706,075	10,186,108	9,541,858	88.1	42.1	130.2
Storage Bunkers	15,776,800	28,019,597	13,520,718	86.0	72.6	158.6
Silo Covers	879,120	1,740,658	857,142	6.0	5.2	11.2
Custom Farming Operations	23,036,147	35,821,208	22,414,171	117.2	83.2	200.4
HES Capital Investments Total Investment	118,249,295	194,744,878	121,530,925	580.2	536.5	1,116.7
HES Annual Operating Expenses						
Cash Lease Land	3,656,150	5,140,547	3,813,364	19.4	10.0	29.4
All Fuel[a]	6,846,518	10,913,350	7,209,384	72.3	27.6	100.0
All Repair and Maintenance	3,324,580	5,169,722	3,234,817	16.9	12.0	28.9
Poly Pipe	98,272	114,978	107,706	1.0	0.5	1.5
Fertilizer, Herbicide, and Seed	11,036,137	22,226,779	14,678,062	390.4	70.6	461.0
Full-Time Labor and Overhead Management	12,738,990	25,106,335	7,363,968	254.5	81.7	336.2
Financial Services	962,277.51	1,485,756	999,806	3.3	3.5	6.9
HES Annual Operating Expense	38,662,925	70,157,468	37,407,107	757.8	206.0	963.8
Total Impact	$156,912,220	$264,902,346	$158,938,031	1,338.0	742.5	2,080.5

Table A32. Economic Impacts of Cow/Calf Enterprise in Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria Counties for the Startup Year, 2010.

Expense Item	Direct Impact ($)	Economic Output ($)	Value Added ($)	Direct Employment per $1 million	Indirect and Induced Employment per $1 million	Total Employment per $1 million
Cow-Calf Income	$16,362,157	$29,141,002	$9,480,234	339.2	116.9	456.10

Table A33. Summary of Economic Impacts of Producing HES for Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria Counties for the Startup Year, 2010.

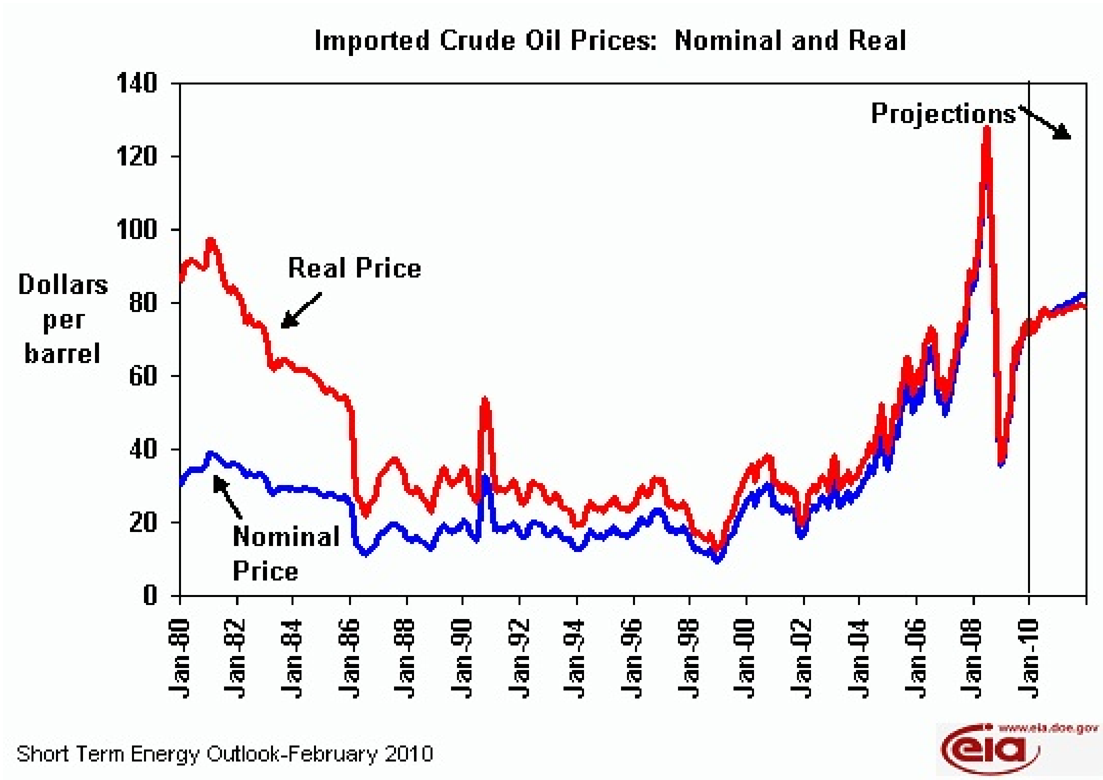
Item	High-Energy Sorghum	Cow-Calf Enterprise	Net Gain
Direct Impact	$156,912,220	$16,362,157	$140,550,063
Output Impact	264,902,346	29,141,002	235,761,343
Value Added Impact	158,938,031	9,480,234	149,457,797
Jobs Supported	2,080.5	456.1	1,624.4

Table A34. Summary of Economic Impacts of Producing HES for Wharton, Lavaca, Colorado, Austin, Fort Bend, Harris, Brazoria, Matagorda, Jackson, and Victoria Counties for Year 2, 2011.

Item	High-Energy Sorghum	Cow-Calf Enterprise	Net Gain
Direct Impact	$38,662,925	$16,362,157	$22,300,767
Output Impact	70,157,468	29,141,002	41,016,466
Value Added Impact	37,407,107	9,480,234	27,926,873
Jobs Supported	963.8	456.1	507.7

APPENDIX B

TEXT FIGURES



Source: Bureau of Transportation Statistics (2010).
Real prices are expressed in 2009 dollars.

Figure B1. Historical and Forecasted Real (2009 dollars) and Nominal Imported Crude Oil Prices, 1980-2010.

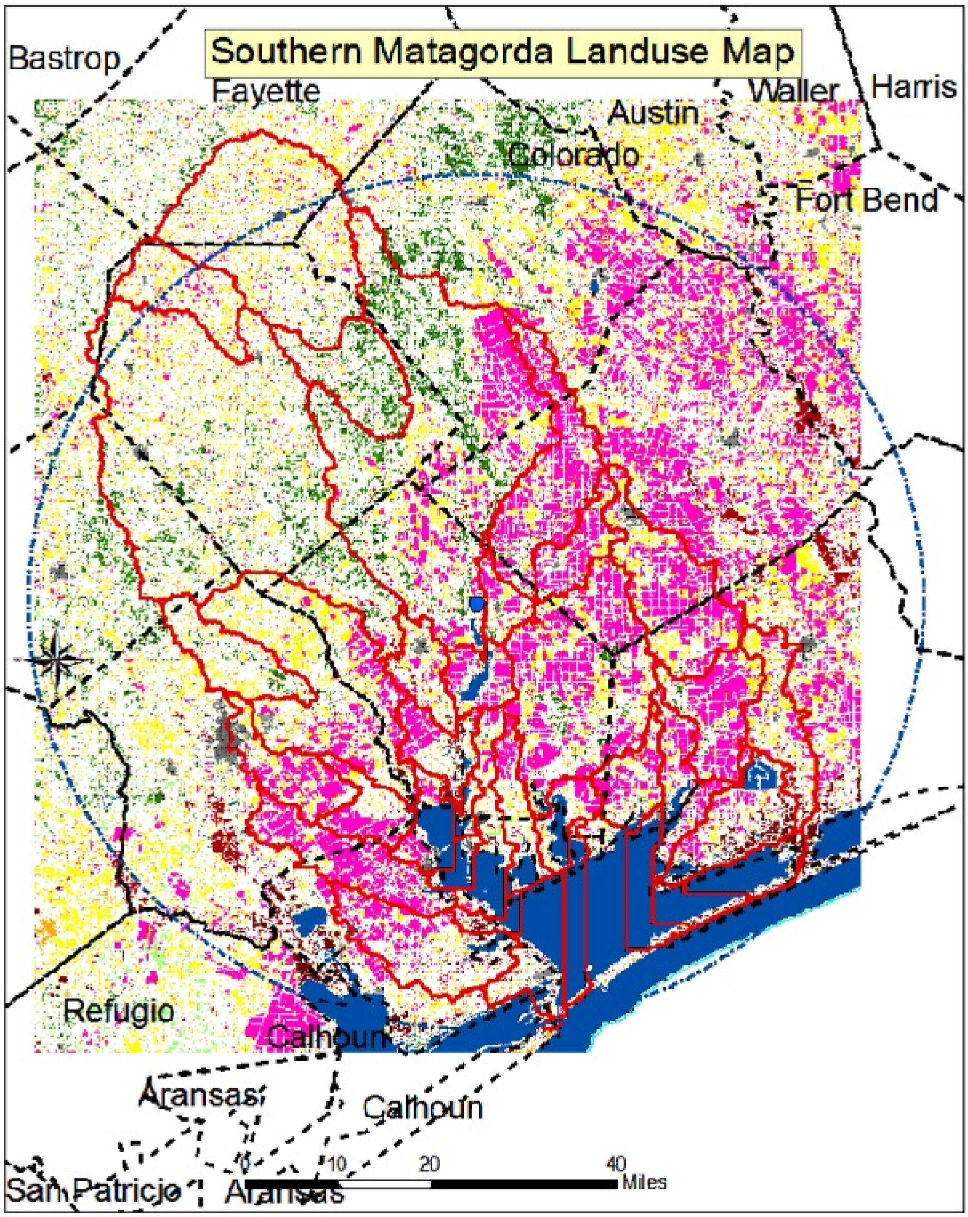


Figure B2. Hypothetical Corporate Farming Operation Region Located Near Middle Gulf Coast Edna-Ganado, Texas Area, 2010.

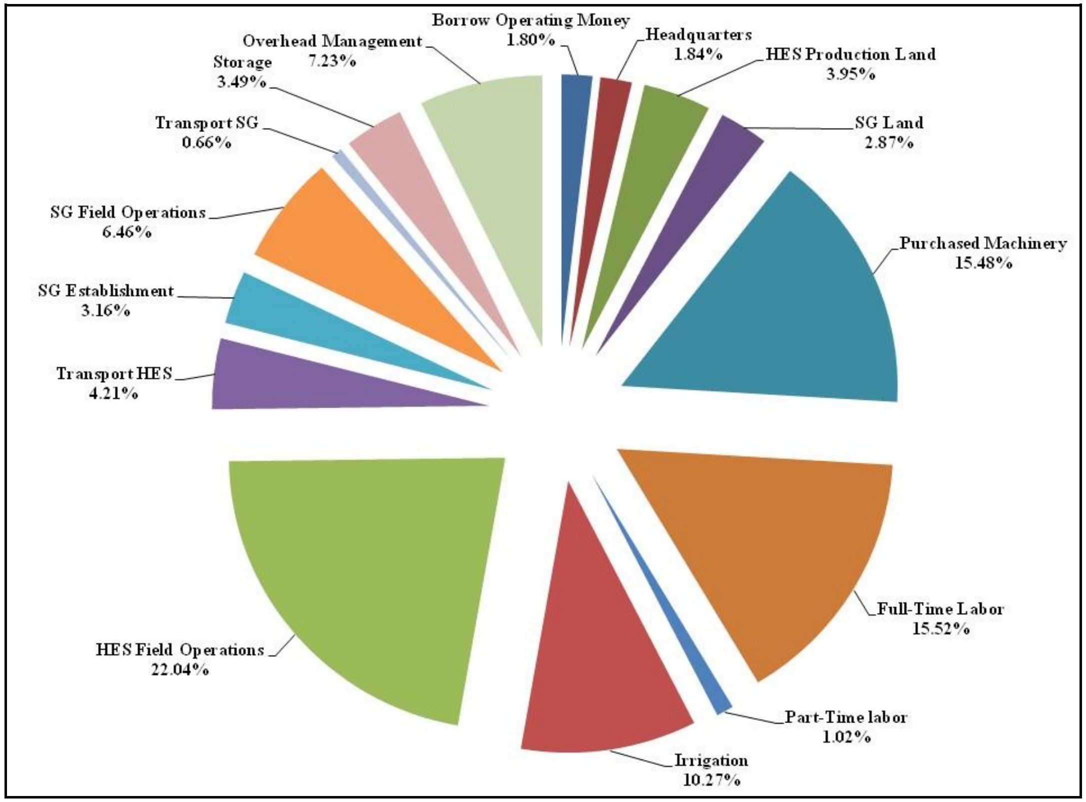


Figure B3. Year 2 Baseline Scenario Total Costs by Major Costs Segment, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

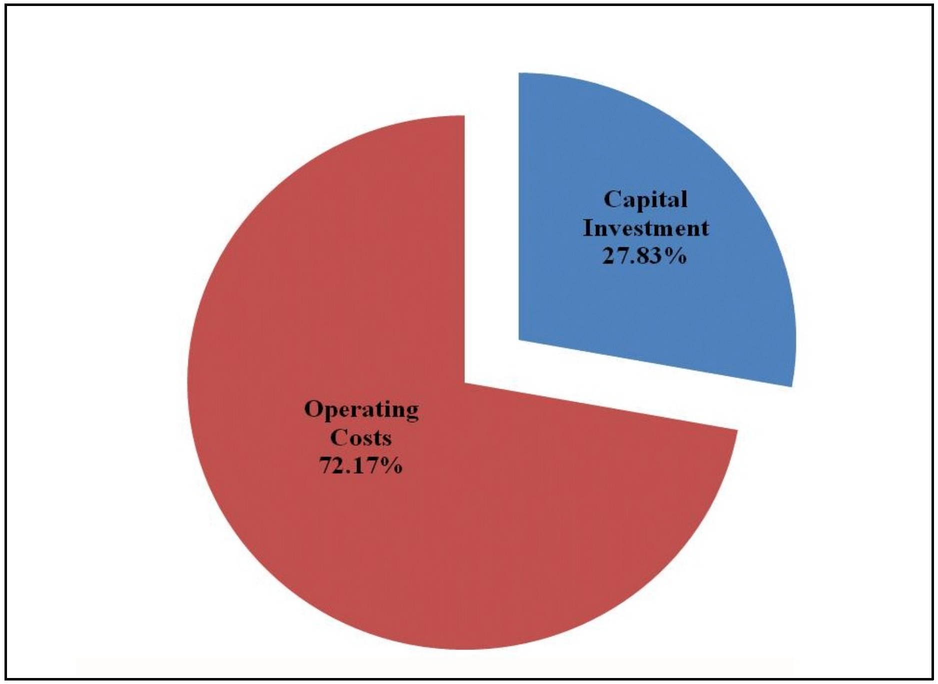


Figure B4. Summary of Total Annual Cost for Year 2 Baseline Scenario, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

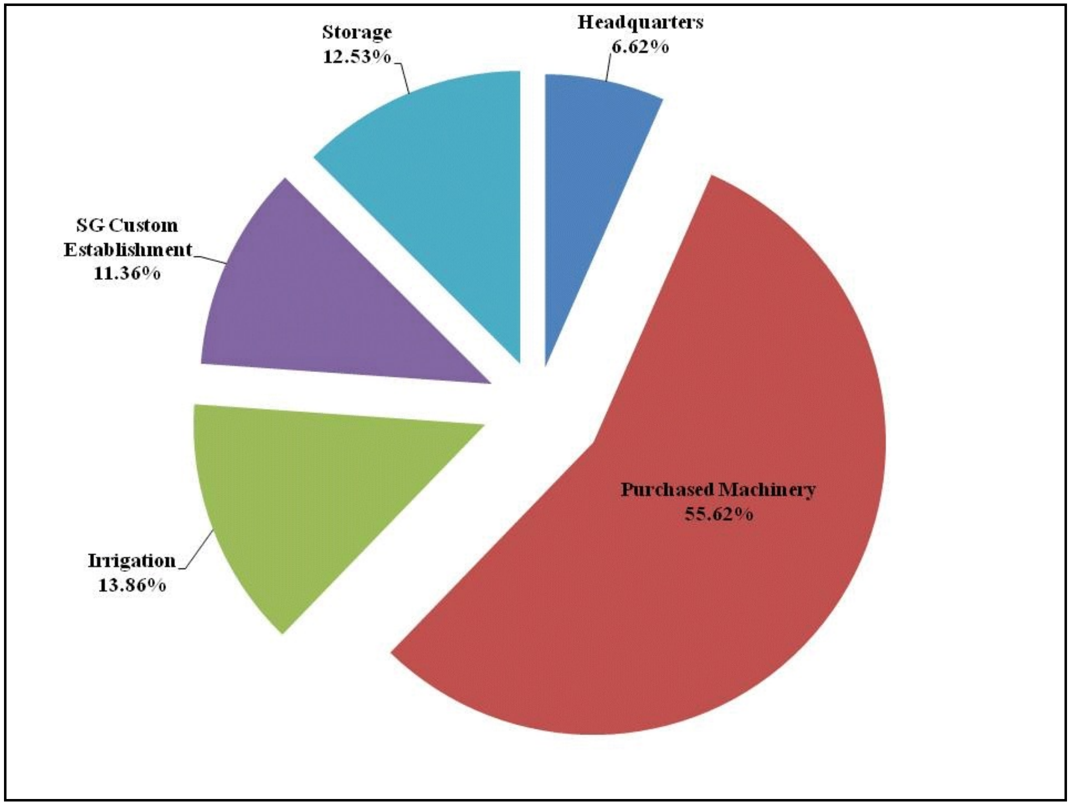


Figure B5. Summary of Year 2 Baseline Scenario Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

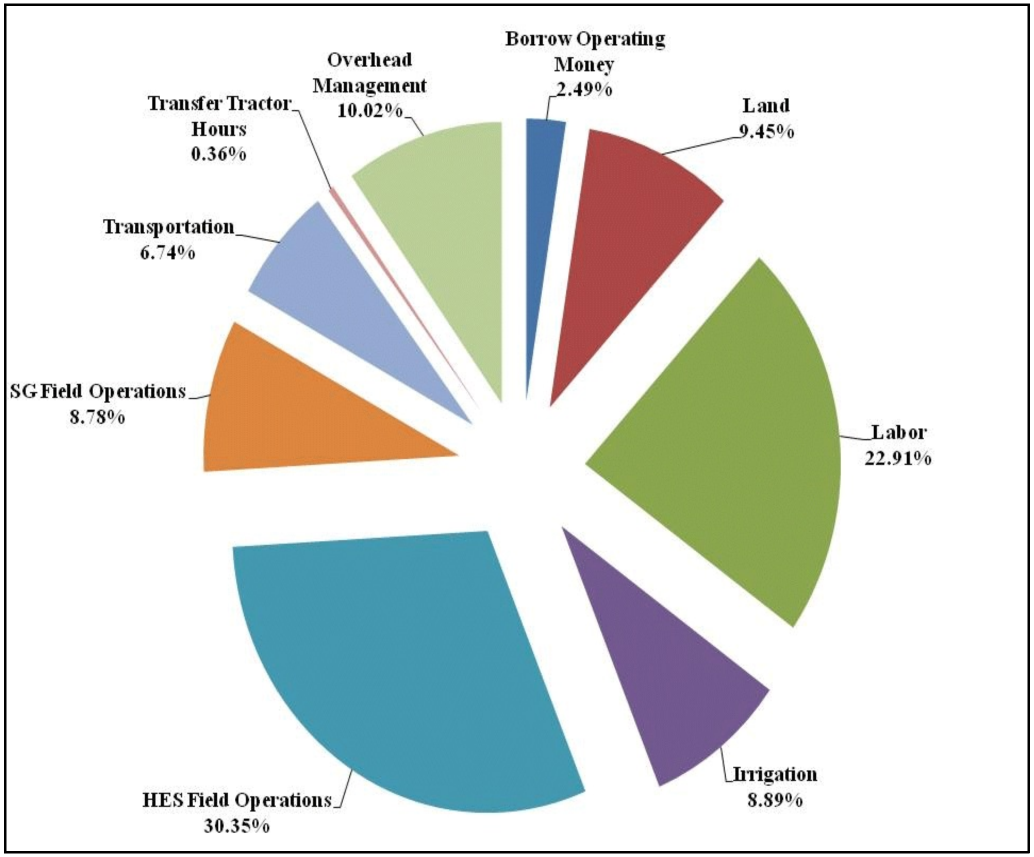


Figure B6. Summary of Year 2 Baseline Scenario Annual Operating Cost, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

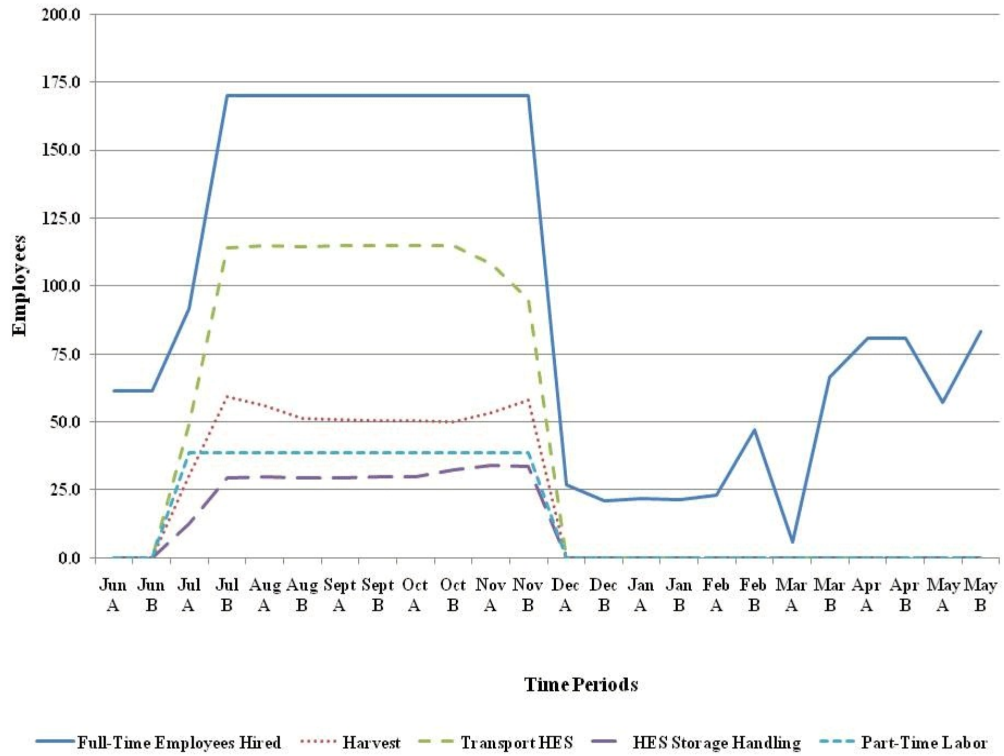


Figure B7. Full-Time and Part-Time Labor Hires and Requirements for Year 2 Baseline Scenario, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

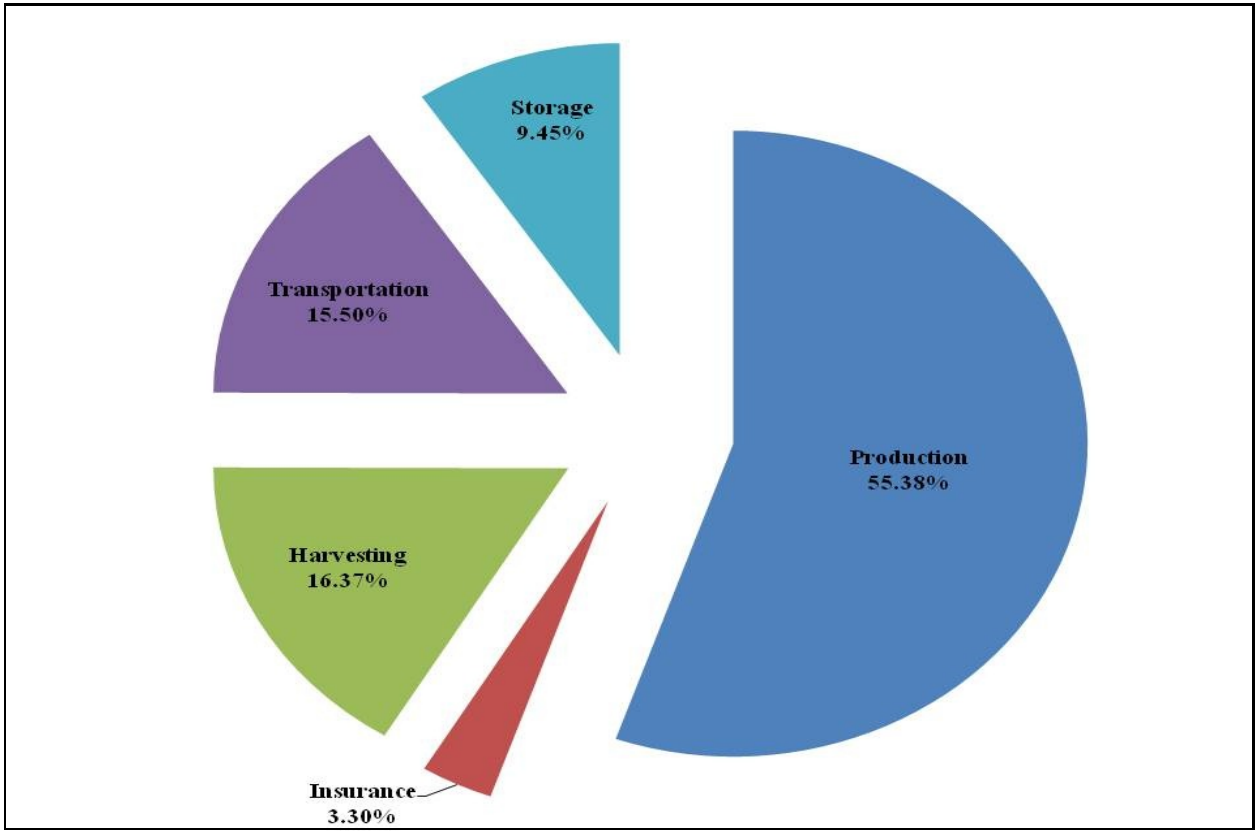


Figure B8. Summary of Logistics Costs for Year 2 Baseline Scenario, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

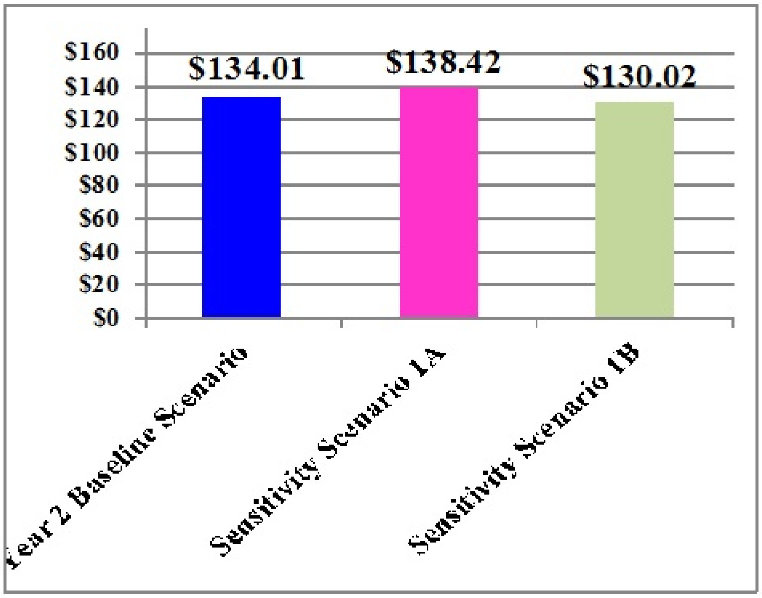


Figure B9. Sensitivity Scenario Category 1 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Cellulosic Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

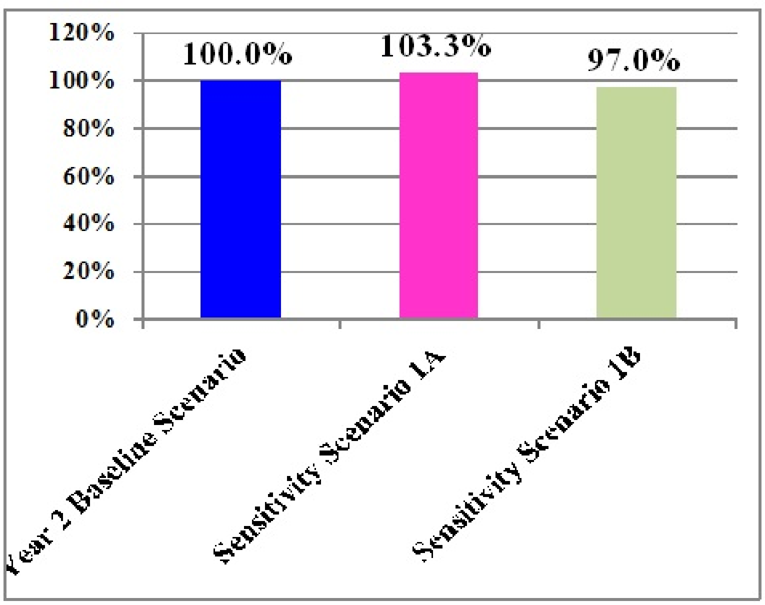


Figure B10. Sensitivity Scenario Category 1 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Cellulosic Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

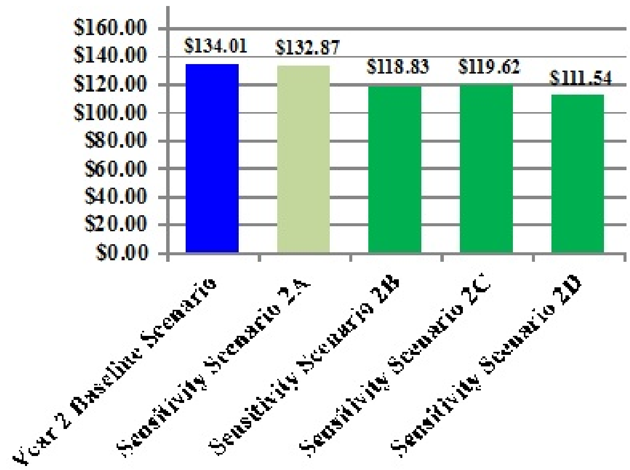


Figure B11. Sensitivity Scenario Category 2 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

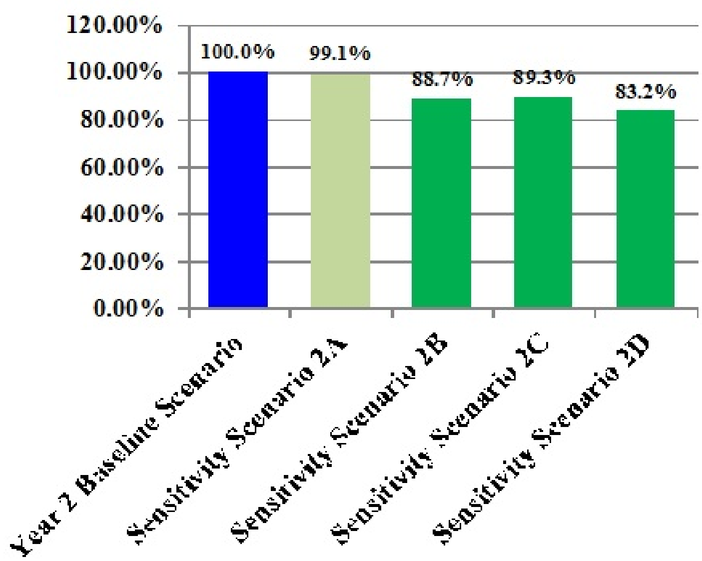


Figure B12. Sensitivity Scenario Category 2 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Scenario Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

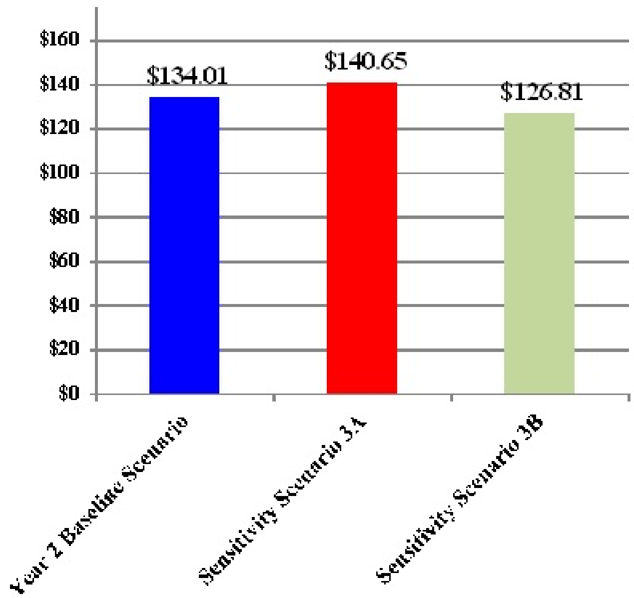


Figure B13. Sensitivity Scenario Category 3 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

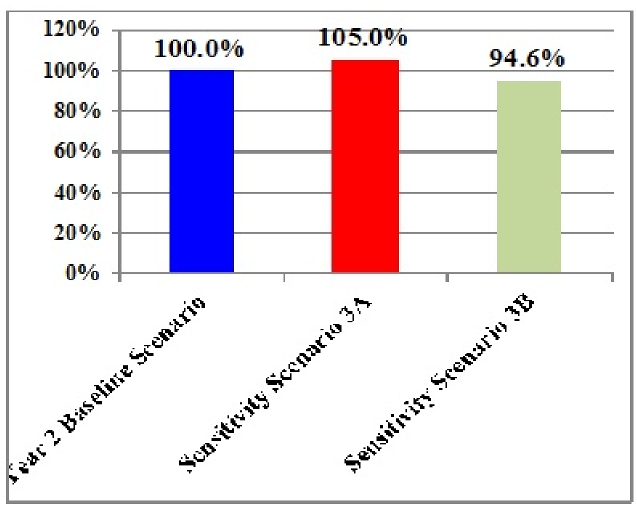


Figure B14. Sensitivity Scenario Category 3 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

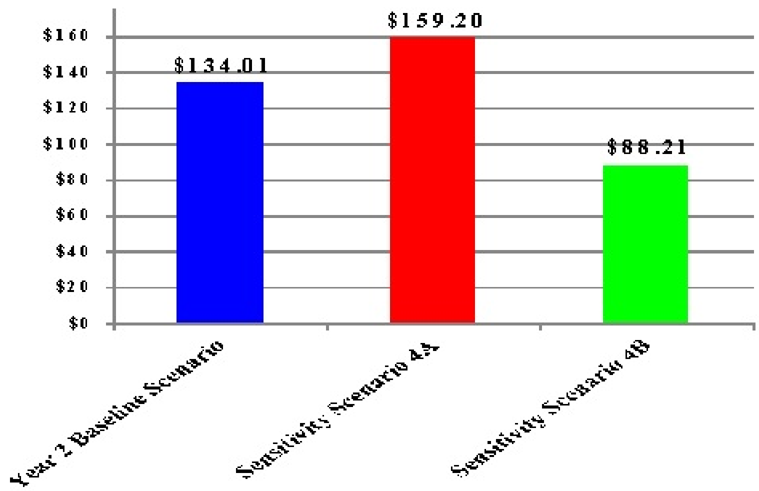


Figure B15. Sensitivity Scenario Category 4 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

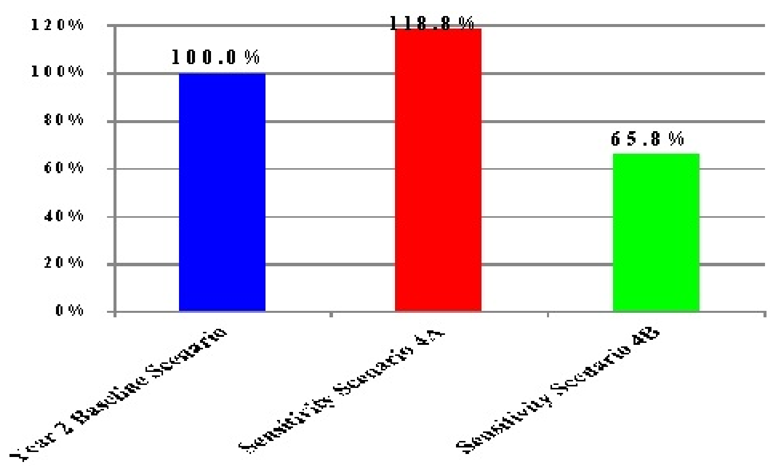


Figure B16. Sensitivity Scenario Category 4 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Scenario Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

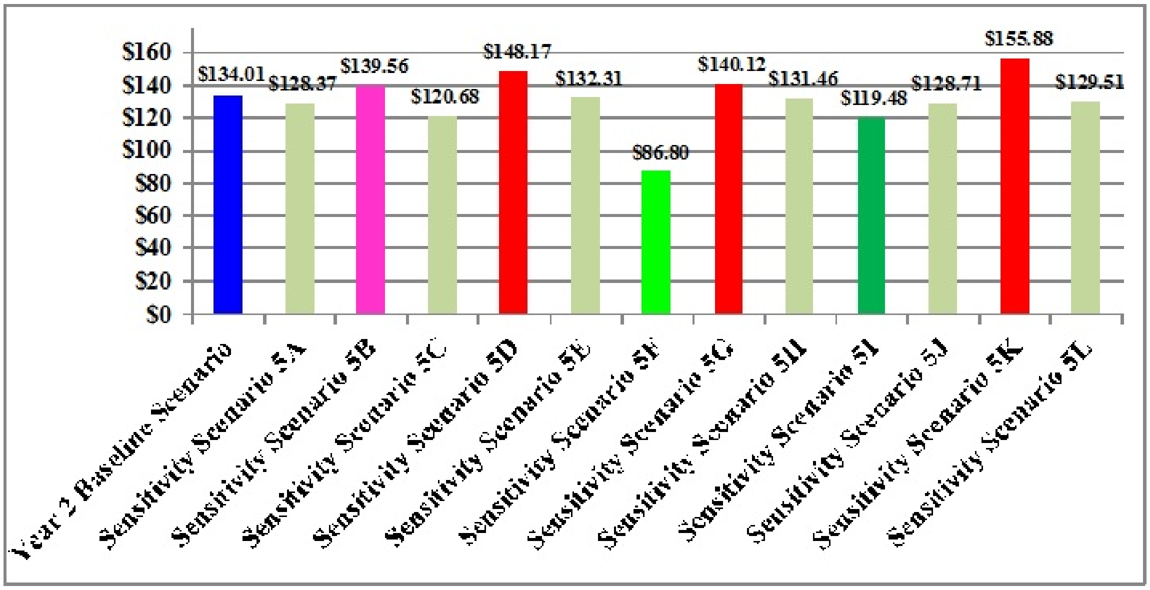


Figure B17. Sensitivity Scenario Category 5 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

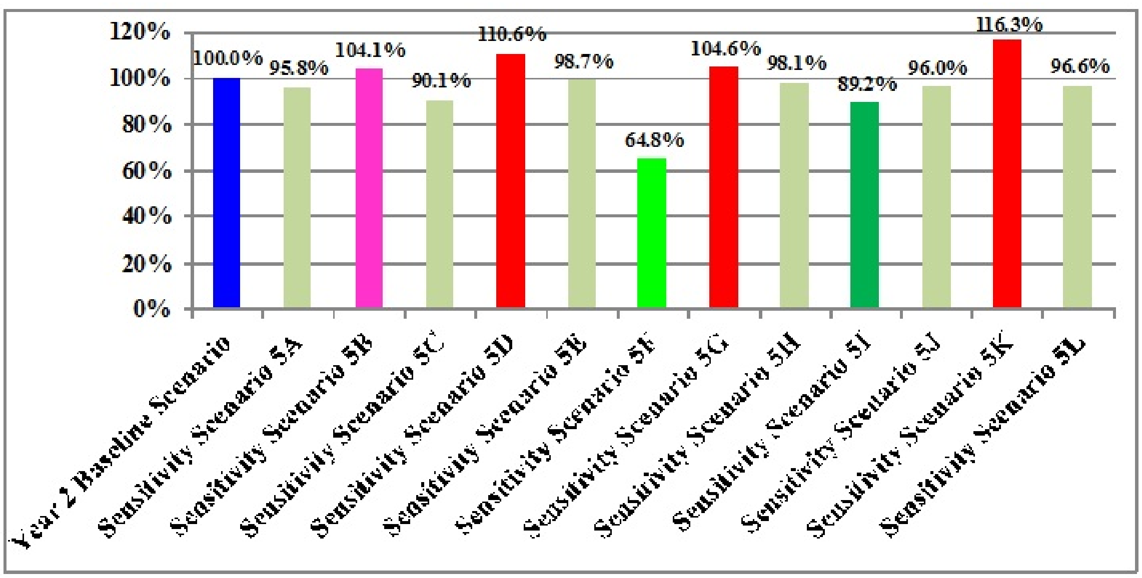


Figure B18. Sensitivity Scenario Category 5 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

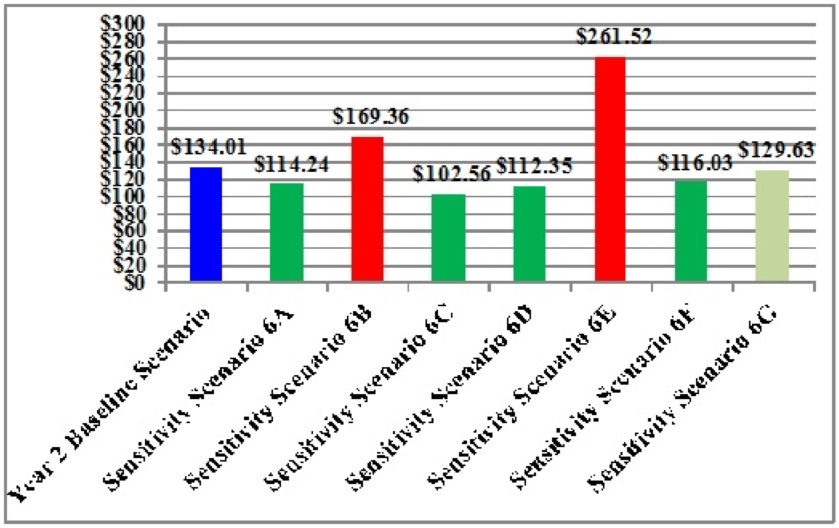


Figure B19. Sensitivity Scenario Category 6 - Cost per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

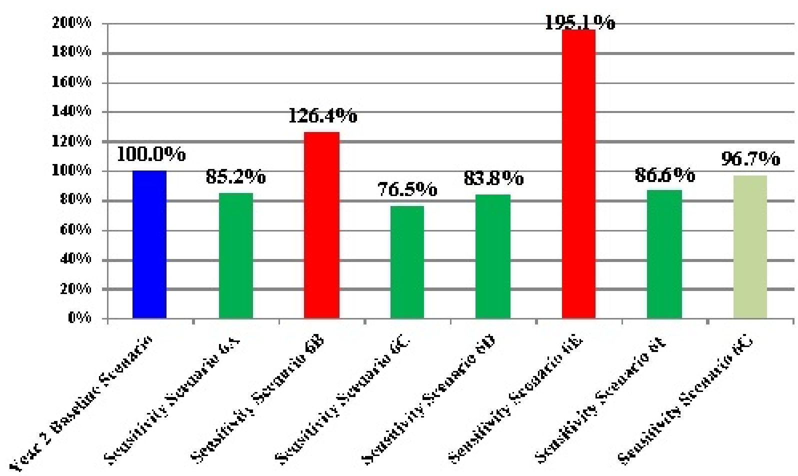


Figure B20. Sensitivity Scenario Category 6 – Costs per Ton of Dry Feedstock Delivered and Stored and 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Scenario Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

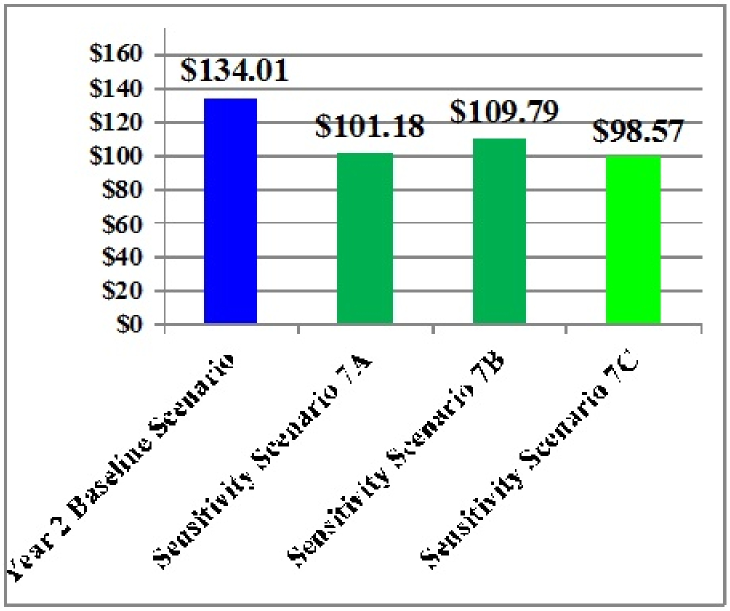


Figure B21. Sensitivity Scenario Category 7 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

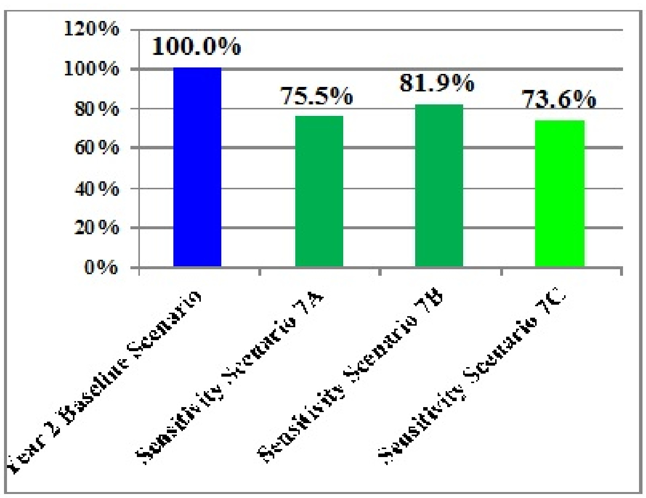


Figure B22. Sensitivity Scenario Category 7 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

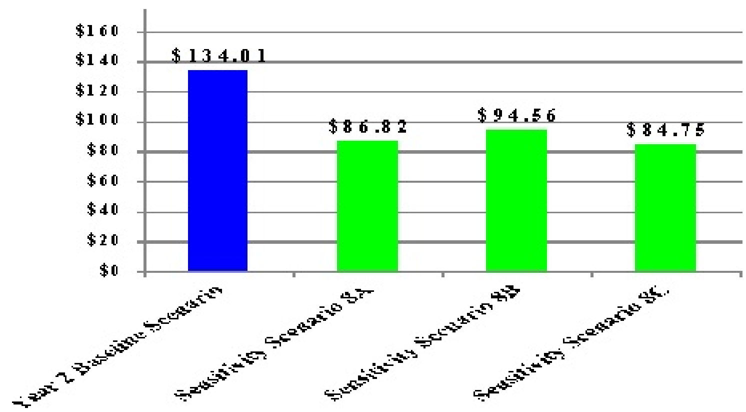


Figure B23. Sensitivity Scenario Category 8 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

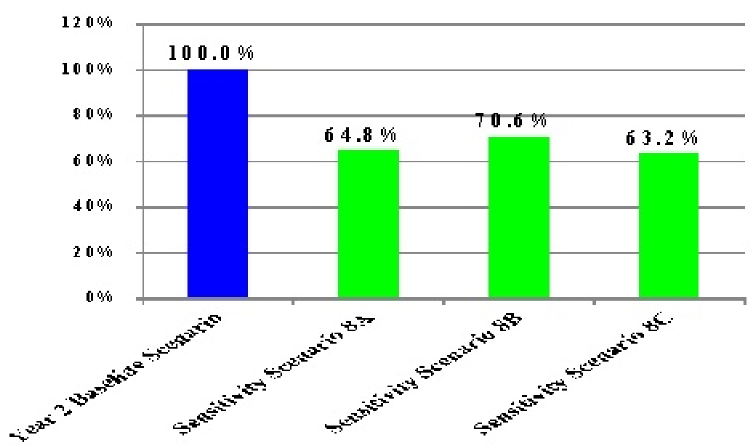


Figure B24. Sensitivity Scenario Category 8 – Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Scenario Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

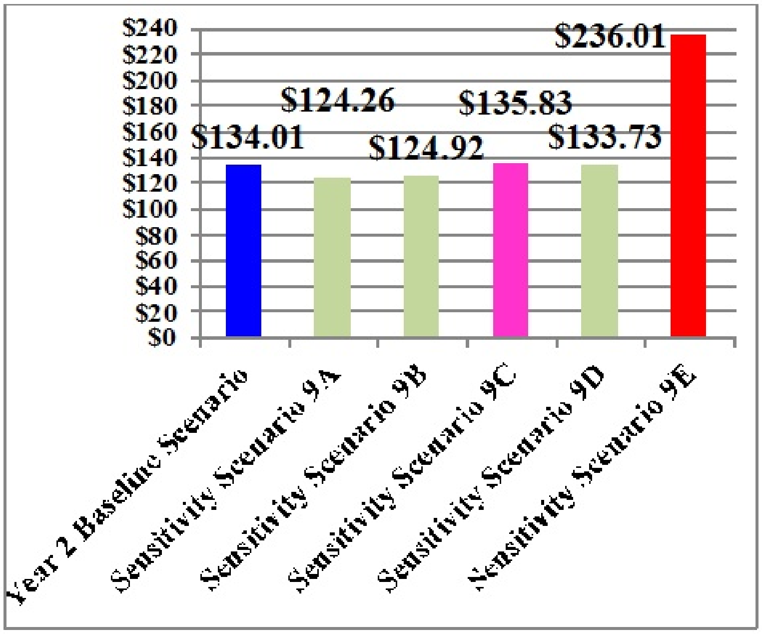


Figure B25. Sensitivity Scenario Category 9 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

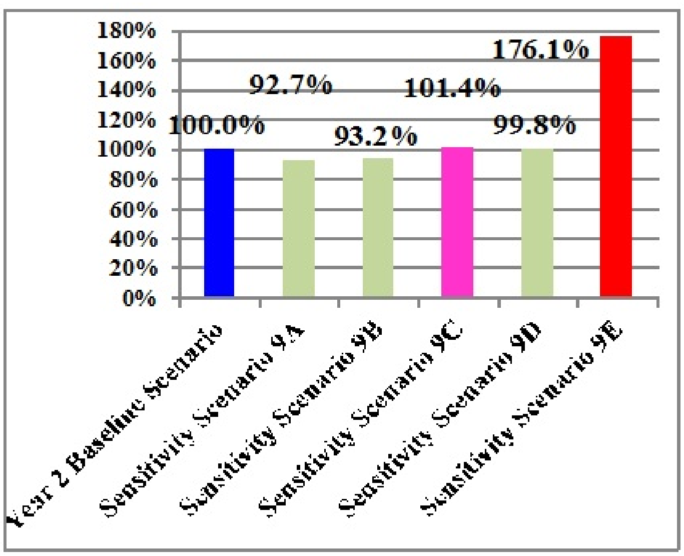


Figure B26. Sensitivity Scenario Category 9 - Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Expressed as Percent of Year 2 Baseline Results, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

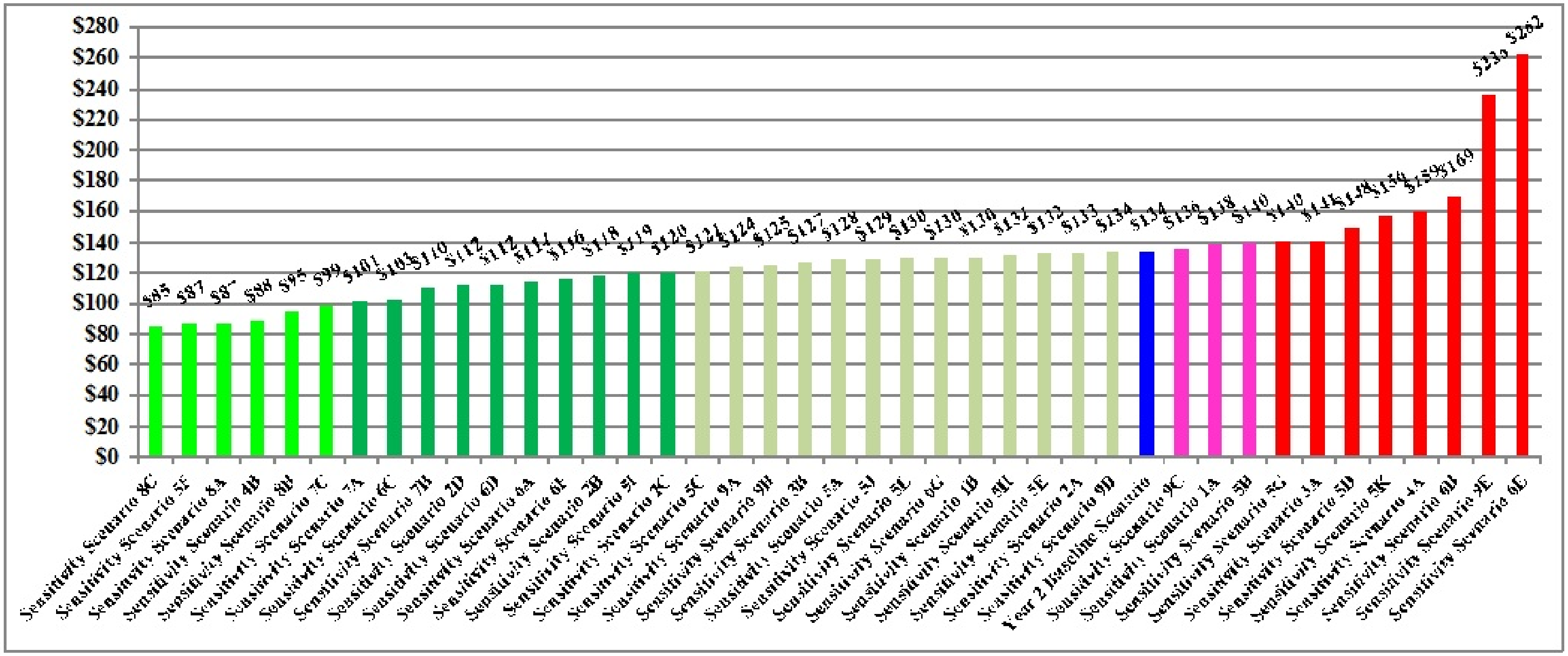


Figure B27. Summary of All Sensitivity Scenarios Relative to Baseline Scenario - Ascending Order of Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

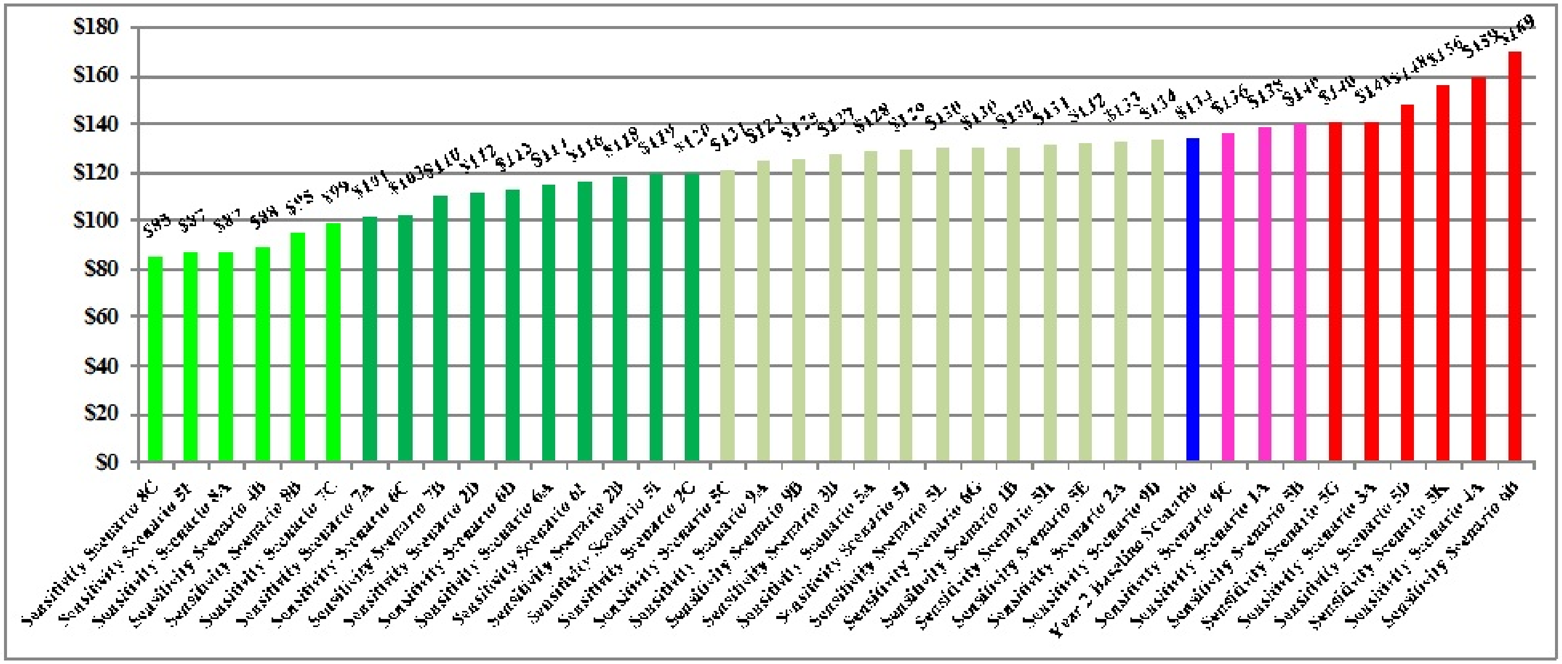


Figure B28, Summary of All Sensitivity Scenarios Relative to Baseline Scenario - Ascending Order of Costs per Ton of Dry Feedstock Delivered and Stored Adjacent to 30-Million Gallon Conversion Facility, Without Economies of Size Scenarios 6E and 9E, Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

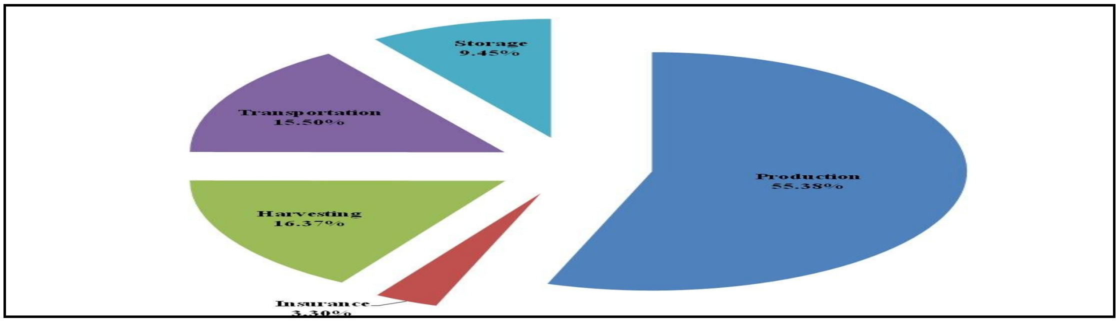


Figure B29a. Summary of Logistics Costs for Year 2 Baseline Scenario, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

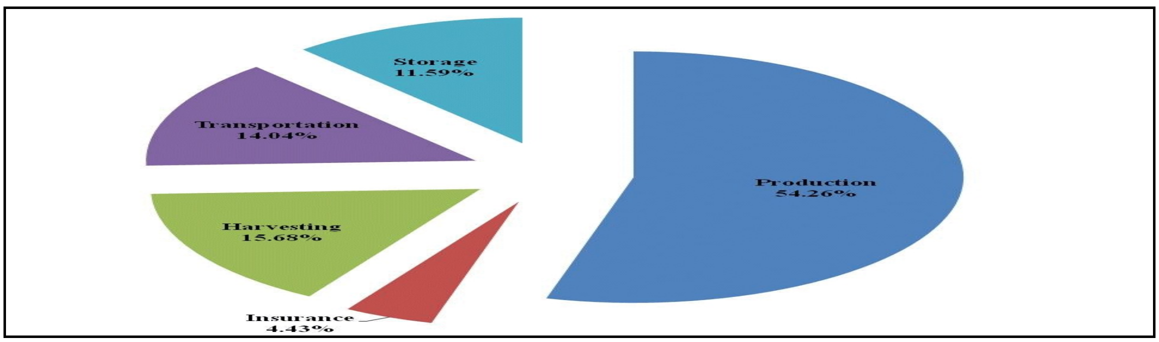


Figure B29b. Summary of Logistics Costs for Sensitivity Scenario 8C, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Feedstock Farming Entity, 2010.

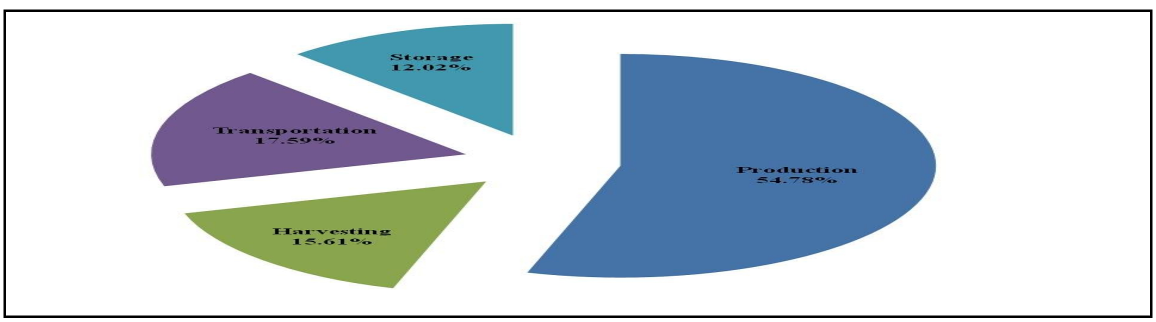


Figure B29c. Summary of Logistics Costs for Sensitivity Scenario 6E, Hypothetical Middle Gulf Coast Edna-Ganado, Texas Area Corporate Feedstock Farming Entity, 2010.

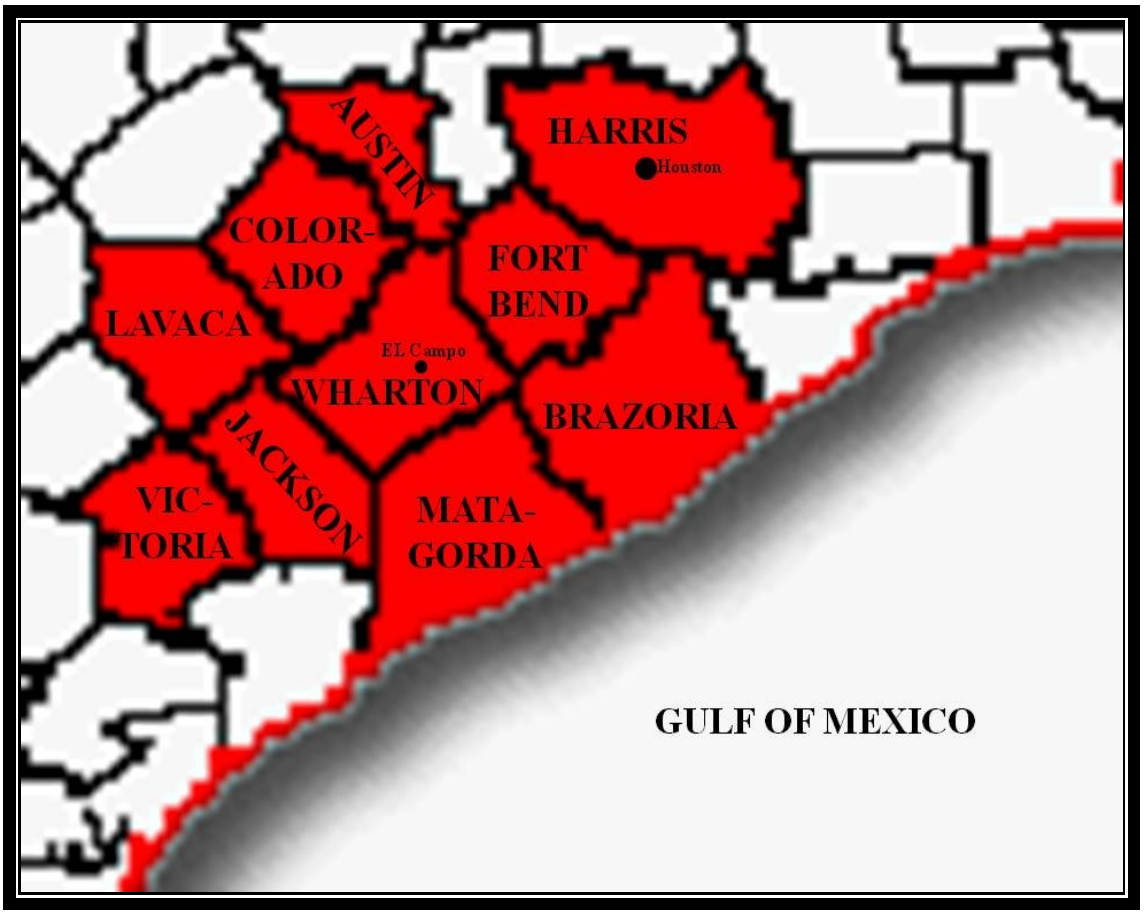


Figure B30. Map of Upper Coastal Bend of Texas Showing Ten-County Region Study Area.

APPENDIX C

TEXT EXHIBITS

Exhibit C1. Summary of Biomass Feedstocks Logistics Costs Estimates Cited in the Literature, 2010.

Literature Source	Year of Estimate	Feedstock Type	$ per ton / % of total costs					Percent of Total Fuel Sales Prices
			Production	Harvesting	Transportation	Storage	Total	
Hess, Wright, and Kenney (2007)	2007	baled straw	$11-44/ton	$15/ton	$11/ton	$5/ton	$42-75/ton	
Fales, Hale, and Wilhelm (2007)	2007	cellulosic biomass						35-65
Fumasi, Richardson, and Outlaw (2008)	2008	high-biomass sorghum (HBS) green chop, hybrid sorghum hay, hybrid sorghum green chop, and billeted hybrid sugarcane		50-75% across all feedstock types; $32/ton for HBS (performed by the biorefinery)				
Larson et al.	2010	switchgrass round bale, switchgrass rectangular bale, and switchgrass preprocess bale	$21/ton	29-18/ton	$15-20/ton	$16-30/ton	$66-96/ton	
McCutchen, Avant, and Baltensperger (2008)	2008	switchgrass, bioenergy sorghum					$60-90+/ton; $50-60/ton	
Turnhollow 1994	1989	hybrid poplar, sorghum, switchgrass, and energy cane				$7-21/ton; 21-44%	$48-66/ton	

– CONTINUED –

Exhibit C1, continued.

Literature Source	Year of Estimate	Feedstock Type	$ per ton / % of total costs					Percent of Total Fuel Sales Prices
			Production	Harvesting	Transportation	Storage	Total	
Turnhollow 1994	2010	hybrid poplar, sorghum, switchgrass, and energy cane				$7-21/ton; 21-44%	$33-48/ton	
Turnhollow 1994	1989, 2010	hybrid poplar, sorghum, switchgrass, and energy cane		40% of the total costs				
U.S. EPA	2009	corn stover	$44.91, $45.46, and $46.20		$43.18/ton		$88.15, $88.64, & $89.38/ton	
U.S. EPA	2009	corn stover	38.8%	22.6%	38.6%			
U.S. EPA	2009	switchgrass			$25.06/ton; 32.48%		$77.15/ton	
U.S. EPA	2009	switchgrass	$44.20/ton farmgate		$32.95/ton			
U.S. EPA	2009	forest residues	$45.00/ton	$11.00/ton	$14/ton; 25-50%		$70.00/ton	
U.S. EPA	2009	municipal solid waste		$30-40/ton less $30/ton tipping fee	$15/ton	$11/ton for grinding	$26-$36/ton	

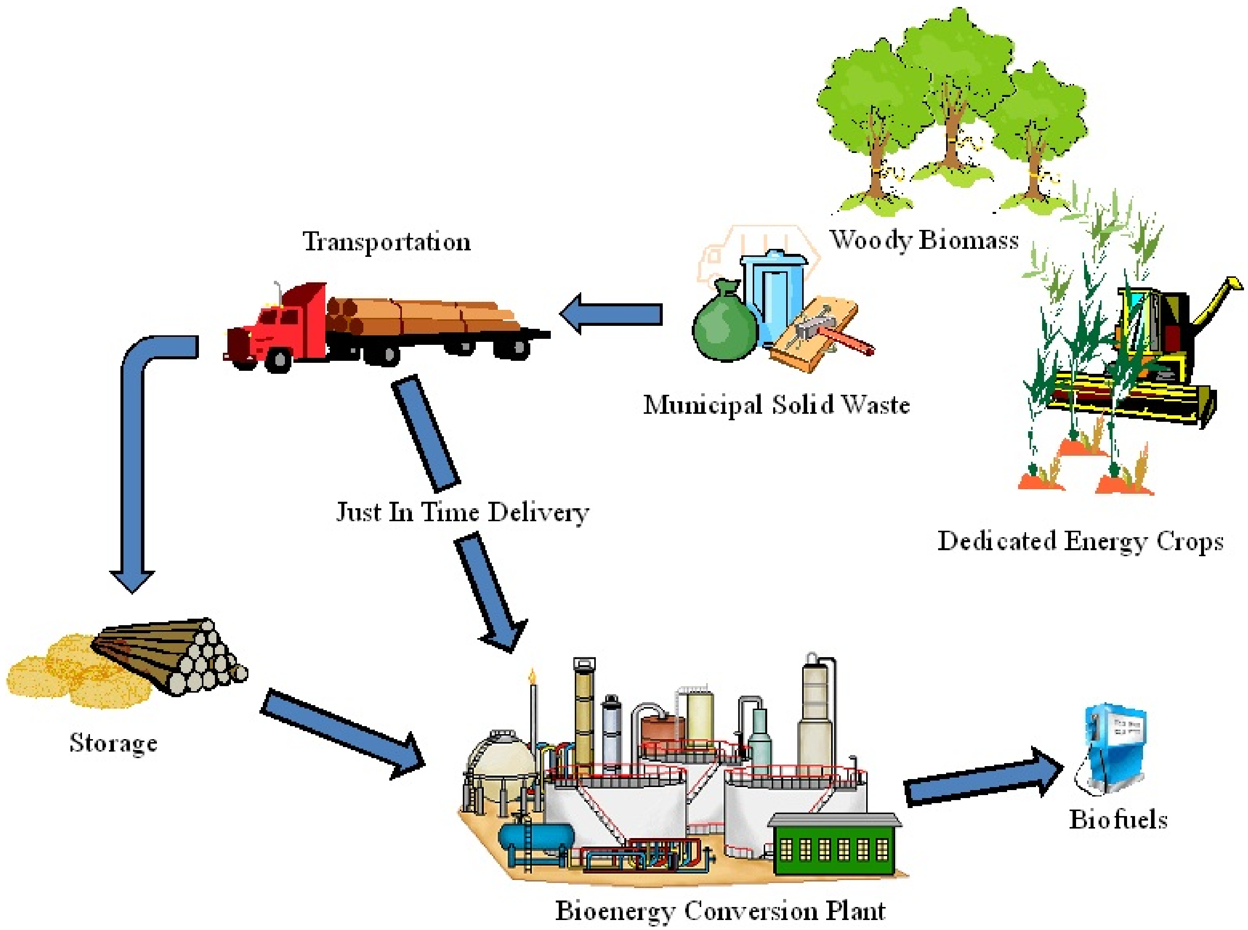


Exhibit C2. Illustration of Logistical Scheme for Bioenergy Feedstock Production, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Table 1. Summary of estimated costs and returns per ACRE
RICE WEST OF HOUSTON - 1ST CROP
450 ACRE FARM, District 11,2010

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
RICE-1ST CROP LOAN	CWT	6.90	70.0000	483.00	_______
RICE-1ST CROP PREM.	CWT	6.00	70.0000	420.00	_______

TOTAL INCOME				903.00	_______
DIRECT EXPENSES					
ADJUVANTS	ACRE	7.00	1.0000	7.00	_______
CUSTOM FERT. APPL.	ACRE	26.52	1.0000	26.52	_______
CUSTOM SPRAY	ACRE	40.56	1.0000	40.56	_______
FERTILIZERS	ACRE	118.06	1.0000	118.06	_______
FUNGICIDES	ACRE	32.50	1.0000	32.50	_______
HERBICIDES	ACRE	74.41	1.0000	74.41	_______
INSECTICIDES	ACRE	16.56	1.0000	16.56	_______
IRRIGATION SUPPLIES	ACRE	10.35	1.0000	10.35	_______
SEED	ACRE	31.50	1.0000	31.50	_______
SURVEY LEVEES	ACRE	5.00	1.0000	5.00	_______
CROP INSURANCE-RICE	ACRE	6.56	1.0000	6.56	_______
IRRIGATION	ACRE	101.46	1.0000	101.46	_______
CHECKOFF/COMMISSION	ACRE	11.20	1.0000	11.20	_______
DRYING - RICE	ACRE	100.57	1.0000	100.57	_______
RICE HAULING	ACRE	28.97	1.0000	28.97	_______
STORAGE - RICE	ACRE	22.40	1.0000	22.40	_______
VEHICLES	ACRE	16.17	1.0000	16.17	_______
OPERATOR LABOR	hour	13.75	1.3603	18.74	_______
RICE WATER LABOR	hour	13.75	1.5700	21.61	_______
DIESEL FUEL	gal	2.05	12.6673	25.97	_______
REPAIR & MAINTENANCE	ACRE	31.84	1.0000	31.84	_______
INTEREST ON OP. CAP.	ACRE	26.84	1.0000	26.84	_______

TOTAL DIRECT EXPENSES				774.79	_______
RETURNS ABOVE DIRECT EXPENSES				128.21	_______
TOTAL FIXED EXPENSES				82.16	_______

TOTAL SPECIFIED EXPENSES				856.95	_______

Source: Texas Agrilife Extension Service (2010)

Exhibit C3. Enterprise Budget for Rice Production in Middle Gulf Coast, Edna-Ganado, Texas Area, 2010.

APPENDIX D

BASELINE SCENARIO DATA

DATA

This section includes a description of the methods for assimilating the data required to use Sorghasaurus© in evaluating the baseline scenario and sensitivity scenarios for HES production in the Middle Gulf Coast, Edna-Ganado, Texas area. The baseline scenario is used as a benchmark in establishing Sorghasaurus'© capability and for comparison to results from subsequent sensitivity scenario analyses. HES and SG are the only biomass feedstock sources allowed to be delivered to the conversion facility for the baseline scenario. HES is allowed to supply an unrestricted amount of biomass feedstock to the conversion facility whereas SG is restricted to supply up to 25 percent of the total amount of biomass feedstock required by the conversion facility.

Two risk management strategies are incorporated into Sorghasaurus© to provide insurance against sub-par production and/or delays in harvest deliveries to the conversion facility. The first strategy is an extra three periods' (approximately six weeks) supply of biomass feedstock is produced and maintained in storage at the conversion facility. The second strategy is an additional amount of SG is established to supply 25 percent of the annual amount of biomass feedstock required by the conversion facility, but this SG is not harvested in the baseline scenario. Rather, it is leased out for grazing during December - February, after completion of any HES harvest, at a rate of $5 per acre. In effect, this insurance SG acreage represents a buffer production supply for those years in which HES and/or SG production is less than the expected average yields.[85]

The major data sections required for using Sorghasaurus© include:

- Headquarters;
- Land Resources;
- Machinery Resources;
- Labor Availability and Trafficable Days;
- Irrigation;
- HES and SG Field Operations, including Harvest;
- Available Time Periods for HES Field Operations;
- HES Yield Relationship;
- HES Variable Inputs;
- Transportation;
- Storage Operations;
- Cellulosic Conversion Facility’s Biomass Feedstock Requirements; and
- Overhead Management.

Headquarters

The “headquarters” section facilitates representation of the costs associated with constructing and maintaining a corporate headquarters consisting of a building for

[85] In the event that yields are more than 25 percent deficient in meeting the conversion facility’s requirements, alternative biomass feedstocks would need to be purchased for the additional required supply.

corporate offices and sheds for machinery and equipment maintenance and storage. The headquarters is assumed to be centrally located within an assumed 30-mile radius of the production area to minimize transportation distance of machinery and equipment to HES and SG fields.

The square foot cost for offices (i.e., initial purchase cost of $150 per square foot) is assumed to cover all costs incurred for construction as well as office furnishings consisting of computers, desk, faxes, and all other office equipment needed for the operation (Sturdivant 2010). The square foot cost for pole barns and barns for inside machinery storage (i.e., initial purchase cost of $14 per square foot and $120 per square foot, respectively) include the costs for building and construction (Sturdivant 2010). Annual fixed maintenance and insurance costs are each assumed to be one percent of the purchase price (Rister 2010; Neystel 2010). Baseline scenario headquarters cost information is described in more detail in table D1.

The total amount of land required for the headquarters is assumed to be double that of the space needed for offices and sheds for machinery and equipment storage. This assumption is made to allow ample space for corporate parking, for parking and movement of machinery, and outside storage of equipment.

Office space requirements are determined by the size of the operation (i.e., HES and SG harvested acres). For every acre of land in production, it is assumed that 10 square feet of office space is needed to perform such duties as management and accounting (Rister 2010; Lacewell 2010). This can be modified by the model user.

Storage space for machinery and implements is derived from the dimensions of the machinery with a space inflation factor (i.e., 20 percent of original dimensions) used to allow for space between equipment (table D2)[86]. While semi trucks are stored inside, it is assumed that semi trailers are stored outside.

The office buildings are built on concrete slabs so no road base is needed for this square footage. Road base is used on the remaining headquarters square footage (i.e., parking area, pole barns, and inside barns for machinery shops and storage) to provide an adequate parking area and to allow for machinery movement and parking during inclement weather.

Land Resources

For the base case application of Sorghasaurus©, all land used to produce HES and SG is cash rented. It is assumed that all land rented for production is within a 30-mile radius of the conversion facility and that 15 percent of the land within this area is available for lease, e.g., land currently not being used to produce rice or other row crops (Raun 2010; Popp 2010). HES and SG can be produced on any contracted land. However, the biomass feedstock produced on any given acre is dependant on the contracts with the landowners; therefore, there is no definitive distinction between the HES land and SG land.

[86] The costs noted in the CBFFE headquarters location for pole barns and associated land include an allowance for such facilities near the storage bunkers adjoining the conversion facility to facilitate storage of the machinery and equipment used at that site.

Maximum available acres for lease for HES and SG for the baseline scenario is determined by using Lee's (2010) assessment of the 1.8 million acres of improved pasture/grassland within a 60-mile diameter circle centered along U.S. Highway 59 between Edna and Ganado, just west of El Campo, Texas. That is, of the total 1.8 million acres within the 60-mile diameter production area,[87] approximately 67 percent is improved pasture/grassland. This number is then multiplied by 15 percent (Lacewell 2010) to provide the total number of acres within the production area that are considered available for lease, i.e., 271,433 acres. Since HES and SG are both available as a source of biomass feedstocks in the baseline application and there is no distinction between HES and SG land, the maximum available acres for lease (i.e., 271,433 acres) represents all of the land available for producing both of these biomass feedstocks. The 15 percent of land available is expected to be low enough to not impact rental rates.

To minimize nutrient depletion of the soil, a rotation pattern of one year in HES and two years in pasture or other non-crop producing enterprise is used (Rooney 2010; Blumenthal 2010). Discussions with Rooney (2010) and Blumenthal (2010) indicate that to maintain land productivity and yields, it is not recommended to plant HES crops on the same land in consecutive years. Thus, this rotation technique helps to maintain land productivity by allowing natural nutrient replacement supplemented by commercial

[87] The following calculation is used to find the total acres within a 60-mile diameter circle surrounding (i.e., 30-mile radius) the conversion facility. The area of a circle is calculated as $A=\Pi r^2$, where A is the area of the total circle in which HES and SG production may occur, Π is pi, and r is the radius of the circle. That is, solve $A=\Pi r^2$ or $A=3.14159265 * 30^2 = 2{,}827.43$ mi^2. Recognizing there are 640 acres in one square mile, the area of 2,827.43 mi^2 is equivalent to 1,809,555 acres.

fertilizer application, since, after harvest, little above-ground HES residue is left to incorporate back into the soil for nutrient and organic matter replacement.

As indicated in table A3, base cash rent for HES and SG land is determined as equivalent to the current annual cash rental rate for pasture land, which is approximately $15 per acre (Raun 2010; Popp 2010). It is assumed land must be continually rented from the landowners, even in the years that HES is not produced. Therefore, the total base cash rent each year for one planted acre of HES (out of three acres total, assuming a three-year rotation) of land is $45. During the two rotational years when HES is not produced, it is assumed the land is subleased at a rate of $5 per acre (total income of $10 per acre for the two rotational acres) for use as pasture or other non-crop producing uses by local agricultural producers (i.e., not affiliated with the CBFFE).

An incentive payment of 50 percent of the $45/acre base cash rent rate is used to induce landowners to switch on a long term basis their land from current production into HES and SG; contemporary research by Fewell, Bergtold, and Williams (2011) supports the necessity of such incentive payments. In addition, this rental rate will accommodate the higher property taxes that the landowners will incur due to changing the land use type and associated improvements (e.g., rehabilitation of irrigation wells) made to the land. The average pasture land value in Wharton County, Texas, is $93 per acre while the average land values for irrigated and dryland row crop land are $335 and $310, respectively (Wharton County Tax Assessor Office 2010; Falconer 2011). The increase in property taxes per acre from switching the land use from pasture to irrigated row crop land is $19.98 per acre for the three-year rotation using a 2.75 percent property tax rate

(Rister 2010). Thus, the $22.50 per acre incentive payment is sufficient to cover increases in property taxes due to changing land use types and improvements and also provides a net $2.52 per acre incentive payment to the landowner. The total cash lease rate ($57.50 per planted/HES acre) is calculated as base cash rent plus the incentive payment minus the base income for subleasing.

Land use of the HES land during the two rotation years (i.e., when it is not planted to HES) in the base and stipulated sensitivity scenarios is assumed to be pasture, with the acreage being sublet to non-CBFFE producers, at the $5 per acre rate (net of any costs borne by the lessors for cover crops, fertilizer, etc. to enhance grazing prospects) discussed above. It is perceived by some (Rooney 2011; Harris 2011) that once the noted acreage is transformed into a cultivated state, row crops such as grain sorghum, corn, cotton, and/or soybeans would be grown during the rotation years.[88]

The cash rental rate for SG land targeted to deliver biomass feedstock every year is calculated using the same method as that for HES land except no income is received from subleasing the land, since SG is assumed to be farmed continuously, i.e., does not require a rotation. Thus, a base cash rental rate of $15 per planted acre plus an incentive payment of $7.50 per acre is used for SG production land, i.e., a total of $22.50 per acre (table D3).

[88] Although this perception is contrary to that of producers in the area (Raun 2010; Popp 2010) who believe such land will not be farmed in a cultivated state due to the absence of surplus machinery, equipment, and labor resources in addition to the apparent marginal row crop productivity of the targeted acreage and the lack of government farm program base associated with such acreage (Falconer 2011), a simplified sensitivity analysis (i.e., Scenario 9A) was conducted late in this thesis research to investigate the potential consequences of such greater crop returns. The assumption that the land of concern would be sub-leased by the CBFFE was maintained (i.e., the CBFFE would not directly farm the noted acreage), but the rental income was increased by $50 per acre per year on each of the two rotation acres. The consequences of such greater returns on the rotation acreage were to lower the costs per dry ton of biomass feedstock from $134.01 to $124.26 and the cost per gallon of biofuel from $1.7867 to $1.6568 (tables E142-145).

Extra SG is grown as insurance for the year(s) where weather or other factors results in a shortfall of dedicated HES and SG biomass harvested yields. It is expected that this insurance biomass feedstock will cost less than purchasing alternative biomass feedstocks[89]. The cash rental rate for SG land used for insurance is calculated the same way as HES cash rent. Since the baseline assumption is this for SG that is not harvested, it is assumed to be leased to area ranchers for grazing at a rate of $5 per acre for the periods December through February. SG used for insurance will only be grazed after it is determined that it is not needed by the conversion facility. HES harvest operations end during November. Assuming normal, expected HES and SG harvested yields are realized, there is a brief period during which the insurance SG acreage can be grazed before it needs to be managed for yield insurance protection in the next year. Thus, the net base cash rent is $17.50 per acre for SG insurance land (table D3).

Machinery Resources

An important aspect of any farming operation is to match the power unit sizes with the size of the implements being used. This data section is directed towards handling power units and implements. The next data section, Labor Availability and Trafficable Days, relates to permanent (i.e., full-time) and hourly (i.e., part-time) labor.

Correct choices of power units and implement combinations minimizes machinery costs by ensuring that an oversized power unit is not matched with a small

[89] As discussed elsewhere in this thesis, Falconer (2011) suggests coastal bermuda hay may be a viable insurance strategy for the targeted study area. Absent detailed supply availability and related market supply information, such a strategy is noted as appropriate for future research investigations.

implement or an undersized power unit is not matched with a large implement (Bowers 1975). Unmatched machinery complements can also have a negative effect on machinery capacities. The machinery complements and effective capacities for HES are designated in table D4.

To allow tractors to be fully utilized, and thereby minimize capital investments, in-field buggies can be pulled by either the 225 horse power (hp) tractors or the 152 hp tractors. This allows the 225 hp tractors to be utilized during harvest instead of purchasing additional 152 hp tractors, thereby reducing overall investment requirements.

High-Energy Sorghum Machinery

Determining the capacities of each least-cost combination of machinery is an important part of identifying data to be used in Sorghasaurus©. Machinery capacities are used in combination with trafficable field days (discussed in the next section) to estimate the machinery resources required to perform each field operation in the specified allowed time periods.

Field Operation Machinery

Machinery capacities for all HES field operations except harvest, use of in-field buggies, and storage handling are calculated according to equation 1:

Equation 1. $MC_i = \langle (S_i \times W_i \times E_i \times 5{,}280) \div 43{,}560 \rangle;$

where,

$_i$: represents machinery item;

MC_i : machinery capacity for machinery item i (acres per hour);

S_i : operational speed for machinery item i (miles per hour);

W_i : width of implement for machinery item i (feet); and

E_i : assumed operating efficiency for machinery item i (%).

In this equation, 5,280 represents feet of row length per mile and 43,560 is the number of square feet in a surface acre. Mathematically, MC_i is defined in acres per hour. For example, a planter 38 feet wide operating at a speed of 4.5 miles per hour with an effective capacity of 65 percent has a machinery capacity of 13.47 acres per hour (table D4).

Harvest Buggies

Calculating the machinery capacity of the in-field buggies used to haul harvested HES to the transport trucks at the edge of the field requires several assumptions: (1) it takes 13.5 minutes to travel loaded from the harvester to the truck,[90] three minutes to dump,[91] and 11.5 minutes to travel empty from the truck back to the harvester,[92] and (2) load time is based on the wet tons harvested per acre and the machinery capacity of the harvester.

[90] Travel time from a harvester in the field to unload where an end-dump semi trailer transport truck is parked is calculated based on: (1) average speed of 2.5 mph, and (2) average travel distance of 0.5 miles or the center of one 150-acre field. An extra 1.5 minutes is assessed to account for any delays (Rister 2010; Lacewell 2010).

[91] Dumping the in-field buggies is accomplished by pulling alongside the end-dump semi trailer, using the hydraulic arms on the buggy to lift the silage box, and dumping the silage over the edge and into the end-dump semi trailer.

[92] Travel time from the transport truck back to the harvester to load is calculated based on: (1) average speed of three mph (due to empty buggy), and (2) average travel distance of 0.5 miles or the center of one 150-acre field. An extra 1.5 minutes is accessed to account for any delays (Rister 2010; Lacewell 2010).

The amount of silage one in-field buggy can haul per trip is dependant on the density of the harvested biomass feedstock. The in-field buggies have a capacity of 15 tons, or 1,275 cubic feet. Considering the October B, November A, and November B harvest period data specified for in the Middle Gulf Coast, Edna-Ganado, Texas area, the density of the harvested silage is relatively low and the cubic foot capacity of the in-field buggies restricts the amount of material that can be hauled[93]. During the other harvest period, the density is higher and the tonnage capacity of the in-field buggy restricts the amount of material that can be hauled.

Therefore, to determine the amount of silage hauled per trip for each of these scenarios, the density of the harvested biomass feedstock is multiplied by the cubic foot capacity of the in-field buggy. If the tonnage capacity is exceeded, this number is replaced with the maximum 15-ton capacity of the in-field buggies (Horstline Equipment 2009). This calculation process is demonstrated mathematically in the following set of equations:

Equation 2. $$C_{xy} = \min\left[15\ tons;\ \frac{1{,}275 ft^3 \times D_{xy}}{2{,}000}\right];$$

Equation 3. $$L_{xy} = WY_{xy} \div C_{xy};\ and$$

[93] The drier the harvest moisture is for the HES, the less it weighs per cubic foot, i.e., the less dense it is. The capacities of the buggies are determined by the lesser of their maximum weight capacity or their physical space capacity. At high moisture for the HES, the densities are high and the weight capacity constraint is effective. At low harvest moisture, however, the densities are low and the physical space constraint is effective. That is, the lower the harvest moisture for HES, the lower the weight per cubic foot of space.

Equation 4. $BU = \left[L \div \left(60 \div T\right)\right]$.

where,

C_{xy} : capacity of the in-field buggies (tons) during harvest period x and plant period y;

D_{xy} : density of the harvested biomass feedstock during harvest period x and plant period y;

L_{xy} : number of loads generated per harvester per hour during harvest period x and plant period y;

WY_{xy}: wet yield per acre during harvest period x and plant period y,

BU_{xy} : number of in-field buggies required during harvest period x and plant period; and

T : total loading/travel/unloading time (hours) during harvest period x and plant period.

Two examples are provided to illustrate the calculations for the two extremes of the in-field buggy capacity constraint (i.e., weight constraint of 15 tons or volume constraint of 1,275 cu-ft). The first example demonstrates the calculations for a weight capacity of 15 tons. This calculation is appropriate when HES harvest moisture content exceeds 65 percent. If 34 wet tons are harvested per acre and the machinery capacity of the harvester is 4.61 acres per hour,[94] the time it would theoretically take to load the

[94] Assumes the harvester has an effective operating efficiency of 80 percent.

buggy with 15 tons of biomass[95] would be five minutes and 45 seconds. Adding on the 25 minutes of travel time to and from the truck and the three minutes to dump into the truck represents a total loading/unloading time for one buggy of 33 minutes and 45 seconds. The tons harvested per hour can be calculated by multiplying the machinery capacity of the harvester by the wet tons yield per acre. In this example, each harvester harvests 156.60 wet tons of biomass feedstock that must be hauled to the trucks every hour, i.e., 4.61 acres per hour multiplied by 34 wet tons per acre (at 70 percent moisture content, equivalent to a dry (15 percent) moisture yield of 7.29 tons per acre). Assuming one in-field buggy hauls 15 tons per load because the tonnage capacity is restricting, 10.44 buggy loads are generated each hour by one harvester, i.e., 156.60 wet tons divided by 15 wet tons per in-field buggy load. The number of in-field buggies required for one harvester per hour is calculated by multiplying the buggy loads per hour by the total loading/unloading time for one buggy, and then dividing by 60. This example estimates that 5.88 in-field buggies are required to support each harvester, i.e., 10.44 buggy loads multiplied by 33 minutes and 45 seconds per buggy load divided by 60 minutes. The in-field buggy capacities are calculated in this manner to allow the harvesters to run non-stop during harvest.[96]

An example of an in-field buggy volume capacity of 1,275 cu-ft times density is as follows[97]. This calculation is appropriate when HES harvest moisture content is at or

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[95] 15 tons is the maximum capacity of the in-field buggy based on weight (Horstline Equipment 2009).

[96] An 80 percent efficiency for harvesters is used to account for fueling and any break downs and other unanticipated delays (Falconer 2009).

[97] 1,275 cubic feet is the maximum capacity of the in-field buggy based on volume (Horstline Equipment 2009).

below 65 percent moisture (a rare occurrence as represented in table D14). Assuming the moisture content of the harvested biomass feedstock is 60 percent, a density of 20.80 pounds per cubic foot is used in this example. At this density, the allowed 1,275 cubic feet capacity is equivalent to 13.26 tons of biomass (i.e., 1,275 multiplied by 20.8, and then divided by 2,000 pounds). If 20 wet tons are harvested per acre and the machinery capacity of the harvester is 4.61 acres per hour, the time it would theoretically take to load the buggy with 13.26 tons of biomass would be eight minutes and 37 seconds[98]. Adding on the 25 minutes of travel time to and from the truck and the three minutes to dump into the truck represents a total loading/unloading time for one buggy of 36 minutes and 38 seconds. The tons harvested per hour can be calculated by multiplying the machinery capacity of the harvester by the wet tons yield per acre. Using the above example, 92.12 wet tons of biomass feedstock must be hauled to trucks every hour, i.e., 4.61 acres per hour multiplied by 20 wet tons per acre. Assuming one in-field buggy hauls 13.26 tons per load because the cubic foot capacity is restricting, 6.95 buggy loads are generated each hour by one harvester, i.e., 92.12 wet tons divided by 13.26 wet tons per buggy load. The number of in-field buggies required for one harvester per hour is calculated by multiplying the buggy loads per hour by the total loading/unloading time for one buggy, then dividing by 60. This example estimates that 4.24 in-field buggies are required for each harvester, i.e., 6.95 buggy loads multiplied by 36 minutes and 38 seconds per buggy load divided by 60 minutes. All these relationships are incorporated

[98] The wet yield for this example is calculated from the Plant/Harvest matrix (table D14). This example uses 20 wet tons as opposed to the previous example using 34 wet tons because a moisture content of 60 percent provides a small-enough density to demonstrate the capacity constraint effectively.

into Sorghasaurus© so the model's output accounts for the capital investment and operating costs of all machinery, labor, etc.

Storage Handling Equipment

The capacity of the storage-handling equipment for each HES harvest period is presented in table D5. This capacity is dependant on the size of the bucket (i.e., how many cubic feet of material one bucket can haul) and the density of the biomass feedstock. An average moisture content of the harvested biomass feedstock is used to determine the density. A three-yard bucket is used at the storage site in the base analysis to move and store the HES silage. It is assumed the wheel loaders have an effective operating efficiency of 80 percent and it takes one and a half minutes to move and store one bucket load (i.e., scoop and dump). Therefore, one wheel loader has the capacity to transport a maximum of 32 bucket loads of silage per hour at 80 percent efficiency, i.e., 60 minutes multiplied by 80 percent, divided by 1.5 minutes. The tons of silage each bucket load is capable of transporting is dependant on the density of the biomass feedstock. This calculation is determined by multiplying the density of the biomass feedstock by the bucket size. Tons per hour capacity is determined by multiplying the bucket loads per hour by the tonnage capacity of one bucket. Equation 5 is used to calculate the effective capacity of the storage handling equipment:

Equation 5. $SHC^{HES} = \left\langle \left[\left(\left(D_{xy} \times \left(BS \times 27 \right) \right) \div 2000 \right) \times \left(60 \div CT \right) \right] \times E \right\rangle;$

where,

SHC^{HES} : HES storage handling equipment capacity (tons per hour);

D_{xy} : density of the biomass feedstock in harvest period x and planting period y (lbs/cu-ft);

BS : bucket size (cubic feet);

CT : bucket cycle time (minutes); and

E_{wl} : efficiency level for wheel loader.

An example is provided to demonstrate this calculation. For a moisture content of harvested biomass feedstock of 65 percent, there is a density of 23.4 pounds per cubic foot. The wheel loaders are equipped with a three-yard bucket. At 100 percent efficiency, the wheel loader can carry a maximum capacity of 1,895.4 pounds per bucket load, i.e., 23.4 pounds per cubic foot multiplied by the three-yard bucket multiplied by 27 cubic feet in a yard. Dividing 1,895.4 pounds per bucket load by 2,000 pounds represents the fraction of a ton hauled per bucket load, i.e., 0.947. To find bucket loads per hour at 100 efficiency, 60 minutes is divided by the bucket cycle time, i.e., 60 minutes divided by one minute and 30 seconds equates to 40 bucket loads per hour. Multiplying the fraction of a ton hauled per bucket load by the bucket loads per hour at 100 percent efficiency represents the tons hauled per hour at 100 percent efficiency. This calculation equates to 37.9 tons hauled per hour. To find the tons hauled per hour at 80 percent efficiency, 37.9 tons per hour is multiplied by 80 percent efficiency, resulting in 30.33 tons per hour.

Labor

Labor requirements for performing field operations, in-field transportation, and storage activities are based on the machinery capacities. A labor adjustment factor of 30 percent is added to account for any additional time needed for fueling, repairs, and transporting machinery between fields. Thus, for each hour of operation for machinery and implements, 1.3 hours of labor are required (Rister 2010).

Switchgrass

The machinery complements and capacities presented in table D6 represent the requisite combinations of equipment for SG production. All machinery capacities except haul-and-stack and storage handling were determined using equation 1. The machinery capacity for the SG haul-and-stack operation was determined under several assumptions: (1) 10 bales are hauled per trip (New Holland 2010), (2) it takes 8.6 minutes to travel from the baling site in the field to the side of the field where the stack area is located,[99] it takes two minutes to stack 10 bales, and it takes 7.5 minutes to travel back to the field to pick up 10 more bales,[100] and (3) haul-and-stack capacity is dependant on dry tons harvested per acre.

To determine haul-and-stack machinery capacity per period, the weight of the "square" bales[101] is required. This is accomplished by multiplying the cubic foot

[99] Travel time to the side of the field to stack is calculated based on: (1) average speed of 3.5 mph, and (2) average travel distance of 0.5 miles or the center of one 150-acre field.
[100] Travel time to pick up to more bales is calculated based on: (1) average speed of 4.0 mph, and (2) average travel distance of 0.5 miles or the center of one 150-acre field.
[101] Although actually rectangular in shape, the SG bales are referred to as square per "real–world vernacular" (Rister 2010).

composition of a bale (96 cu-ft)[102] by the density of the baled SG (8.3 pounds per cu-ft) (McLaughlin, Samson, and Bransby 1996). The tons harvested per period are then converted into pounds and divided by the weight of the "square" bales to determine the number of bales per acre. It is assumed that the bale wagon operates at 3.5 miles per hours and that 13 passes (i.e., 13 windrows) are required on one acre using a 16-foot cutter[103]. Dividing the number of rows per acre by the number of bales per acre equates to the number of windrows required to produce one bale. To determine the distance traveled between bales, the width of one representative square acre is multiplied by the number of windrows required per bale. To account for turning at the end of the rows, 16 feet is multiplied by the number of windrows required per bale. These two calculations are added together to obtain the distance traveled between bales. The time required to load one bale is calculated by (1) first dividing the distance traveled between bales by 5,280 feet per mile and (2) then dividing 3.5 miles per hour by 60 minutes. These two calculated values are then multiplied together to calculate the time required to load one bale. Time required to load one bale is then multiplied by 10 bales per load (New Holland 2010) to obtain total loading time for one 10-bale load on the bale wagon. Finally, adding 18.1 minutes of assumed travel-and-stack time determines the total time required to haul and stack one load.

An example is provided to demonstrate the haul-and-stack machinery capacity calculation. The density of one "square" bale is 796.8 pounds per cubic foot

[102] The "square" bales are three feet tall by four feet wide by eight feet long.

[103] The square root of one acre is 208.71 feet; thus, the width of one representative square acre is 208 feet. Dividing this value by 16 feet equals 13 rows that the bale wagon must travel down to pick up "square" bales.

(McLaughlin, Samson, and Bransby 1996 and own modifications) and 4,500 dry pounds of SG are harvested per acre (2.25 dry tons multiplied by 2,000 pounds). Thus, 5.65 "square" bales are produced per acre. To determine the number of windrows required per bale, 13 is divided by 5.65,[104] i.e., 2.31 windrows per bale. Distance traveled in between bales is calculated by multiplying 208.71 feet by 2.31 and adding 16 feet multiplied by 2.31 to obtain 512.37 feet between each bale. 512.37 is then divided by 5,280 feet per mile and multiplied by 60 minutes and divided by 3.5 miles per hour. This calculation equates to 1.66 minutes to load one bale. 1.66 minutes is then multiplied by 10 bales per load to determine it takes 16.64 minutes to load 10 bales. To calculate total haul-and-stack time, 18.1 minutes of assumed travel time is added to the 16.64 minutes, resulting in an estimated 34.74 minutes to haul-and-stack one 10-bale load. This calculation is demonstrated using equation 6:

Equation 6. $$HS = \left\langle (60 \div T) \div \left[\left((DY \times 2000) \div (C \times D_X) \right) \div 2 \right] \right\rangle;$$

where,

T : total loading/unloading time (hours);

DY : dry yield (tons);

C : cubic foot of one "square" bale; and

D_X : density of SG during period x.

[104] A total of 13 windrows are produced per acre using a 16-foot cutter. This number is determined by taking the square root of one acre (208.71 feet) and dividing it by 16 feet.

In addition to the machinery represented in table D6, a "hay squeeze" is used to load SG "square" bales at the field side and unload SG "square" bales at the conversion facility. The capacity of this equipment item is dependant on the weight of the "square" bales and the time it takes to unload and stack three bales, i.e., the one-time capacity of the hay squeeze. It is assumed that it takes two minutes to pick up and stack three bales.

One hay squeeze can carry an assumed maximum capacity at 100 percent efficiency of 2,390.4 pounds per load by transporting three bales at one time[105]. Dividing 2,390.4 pounds per load by 2,000 pounds represents the fraction of a ton hauled per squeeze load. To find hay squeeze loads per hour at 100 efficiency, 60 minutes are divided by the stack time, i.e., 60 minutes divided two minutes per load equates to 30 loads stacked per hour or 90 "square" bales. Multiplying the fraction of a ton hauled per hay squeeze load by the number of loads stacked per hour at 100 efficiency represents the tons hauled per hour at 100 percent efficiency. This calculation equates to 36 tons hauled per hour. To find the tons hauled per hour at 80 percent efficiency, 36 tons per hour is multiplied by 80 percent efficiency to obtain 28.8 tons hauled per hour or 72 bales. This calculation is determined using equation 7:

Equation 7. $SHC^{SG} = \left\langle \left[\left((BW \times 3) \div 2000 \right) \times \left(60 \div CT \right) \right] \times E_{HS} \right\rangle;$

where,

SHC^{SG} : SG storage handling equipment capacity (tons);

[105] The maximum capacity of the hay squeeze is calculated by: (1) finding the total square feet of three "square" bales (i.e., 96 square foot per bale multiplied by three equals 288 square feet) and (2) multiplying 288 square feet by 8.3 pounds per cubic foot (McLaughlin, Samson, and Bransby 1996), the per cubic foot density of, (i.e., 15 percent moisture) SG bales.

BW : bale weight (pounds);

CT : stack time (minutes); and

E_{HS} : efficiency level for hay squeeze.

Machinery and implement ownership and operating costs for HES and SG are presented in table D7. The salvage values for equipment were determined based on their useful lives and were calculated as a percentage of initial costs (Falconer 2010). Annual fixed maintenance is assumed to be one percent of the purchase price and covers any cost incurred to keep the machinery in working condition during periods of minimal use (Rister 2010). Insurance is calculated as 0.6 percent of the purchase price (Neystel 2010). Property taxes are not assessed on machinery and implements as long as the equipment is used for personal business and not for custom or off farm use. This machinery is considered an "implement of husbandry" and is exempt from property taxes (Texas Comptroller of Public Accounts 2006).

Machinery operating costs are divided into two components: (1) repair and maintenance, and (2) fuel and lubrication. Repair and maintenance costs are calculated as a percentage of initial costs using repair and maintenance coefficients obtained from Falconer (2009). Approximate annual hourly use of machinery and implements for these cost calculations was determined by applying the Sorghasaurus© model using preliminary base data for the hypothetical Middle Gulf Coast, Edna-Ganado, Texas area corporate biomass feedstock farming operation and calculating the hours of use for each acquired tractor and each purchased piece of equipment. Useful life estimates for machinery and implements were adapted using Falconer (2009) crop enterprise budgets. Both the annual use in hours and the useful life in years obtained from Falconer (2009) were multiplied together to determine an upper limit of useful hours for each piece of equipment. Those useful hours estimates were then divided by the annual hours of use determined in the preliminary base run analysis to calculate the useful lives for the respective machinery/equipment items in the hypothetical Middle Gulf Coast, Edna-Ganado, Texas area CBFFE.

The repair and maintenance coefficient and the fuel consumption rate for a rice combine were used to calculate these costs for the HES harvesting machine since a silage harvester is not used in that area (Falconer 2010). The repair and maintenance and fuel costs were obtained for all tractors, all equipment and for the harvester by employing Equation 8:

Equation 8. $RM_i = \langle (IC_i \times RMC_i) \div (UL_i \times AU_i) \rangle;$

where,

$_i$:	represents respective tractor, equipment, and harvesting unit i;
RM_i :	hourly repair and maintenance cost for unit i ($);
IC_i :	initial cost for unit i ($);
RMC :	repair and maintenance coefficient for unit i (%);
UL_i :	useful life for unit i (years); and
AU_i :	annual use for unit i (hours).

Fuel and lube costs are calculated for power units only by using hourly fuel consumption rates obtained from Falconer (2009). A fuel price of \$2.05 for red farm diesel[106] and a lubrication expense rate of 15 percent of the fuel cost is used in this baseline scenario (Producers Cooperative 2009; Falconer 2010). Equation 9 is used to obtain the hourly fuel and lube cost for each power unit:

Equation 9. $$FL_i = \langle (FC_i \times DP_i) \times (1 + LR_i) \rangle;$$

where,

$_i$: represents power unit i;

FL : hourly fuel and lube cost for unit i (\$);

FC : fuel consumption rate for unit i (gallons per hour);

DP : diesel price (\$/gal); and

LR : lubrication expense rate for unit i (%).

[106] "Red farm diesel" is diesel fuel that is dyed red and is intended to be used only on a farm or for farming purposes. This diesel is purchased excise tax free and must be used only for nontaxable uses (U.S. Internal Revenue Service 2009). This diesel price was obtained from Producers Cooperative in the fall of 2009.

Labor Availability and Trafficable Days

Labor resources are used in Sorghasaurus© to perform HES and SG field operations, irrigation activities, and for transporting harvested biomass feedstocks to the conversion facility. Defined in this section are: (1) the number of full-time employees hired, (2) the maximum available hours per full-time employee hired, and (3) the maximum available hours of part-time labor available each period.

The number of available work hours per day and the number of available work days per period are used to determine the labor availability from one employee. This determination is based on the idea that there are a limited number of hours available each period in which work may occur. Consistent with commercial agricultural farming operations (Rister 2010), it is assumed the work day starts at sunrise and ends at sunset. Therefore, the hours available per day for one laborer to work is equal to the day length minus one hour (Parker 1985). The one-hour reduction is intended to allow adequate time for morning startup and afternoon shutdown activities, and lunch breaks. Day lengths and hours available for work are expressed in table D8.

Available work days per period were determined on the assumption that only a limited number of days per period are suitable for performing field operations and transportation activities. These days are deemed "trafficable" and represent the time periods available for work each period (table D8). Trafficable field days account for down time due to weather delays (i.e., wet field conditions). The values expressed in table D8 are based on work by Bordovsky (1979) as reported in Parker (1985) and Whitson et al. (1981). It is assumed the work days available for performing field operations are the same as the work days available for transporting harvested biomass feedstocks. The logic of this assumption is associated with transport of harvested biomass feedstock being a continuation of the harvest operation, with no intermediate on-site storage possible between harvest and transport.

The maximum number of working hours per period is achieved by multiplying the trafficable days per period by the number of work hours per day (table D8). The maximum number of trafficable work hours per period for the baseline scenario was determined at the 75 percent probability level (Parker 1985)[107]. This probability level specification is interpreted to reflect that, on average over an extended number of years, there is a 75 percent probability of having at least the designated number of hours available for work. If one were to increase the probability level of the number of hours being available for work, fewer days could be guaranteed, and vice versa. These maximum hours available per period are used in conjunction with machinery capacities to determine the numbers of each piece of machinery that must be acquired to perform field operations or transportation activities. The maximum available work hour per period are also used to determine the hourly labor availability from one employee. To determine the periodic additions to labor associated with hiring one employee, the maximum hours available for work each period is used. It is assumed, however, that labor requirements per hour of machinery work are 30 percent longer than the machinery

[107] A 75 percent probability level implies that in three out of four years, at least (i.e., a minimum of) the specified number of days per period will be trafficable. This probability level reflects, based on analysis of historical rainfall data for the study area and subjective assessments of related field conditions, the likelihood that field operations may occur for the respective specified number of days during the noted time periods. The 50 and 90 percent probability levels are used for sensitivity analyses (table D8).

will operate,[108] and therefore, machinery time requirements for individual operations are multiplied by 1.3 to reflect those extra labor hours and effectively reduce machinery and equipment capacities by a factor of 0.231 (i.e., 1.0 -(1/1.3)).

Irrigation

An open-canal furrow irrigation system is assumed to be used to irrigate HES in the Middle Gulf Coast, Edna-Ganado, Texas area. It is assumed that canals and laterals already exist and can be used to deliver water to fields (Raun 2010)[109]. Irrigation wells from prior rice production/irrigation were considered for refurbishment but, following discussions with Raun (2010) and Mickelson (2009), the need for new wells to pump groundwater for delivery to the HES fields was assumed[110]. Surface water is available, but is not used due to availability concerns and the evolving policies of the Lower Colorado River Authority (Raun 2010).

Re-lift pumps are used to transfer water from the canal into polyurethane pipe (poly pipe) for furrow irrigation (Raun 2010; Falconer 2010). It is assumed the average field size is 150 acres and that one re-lift pump is needed per field (Falconer 2010; Allen 2010). A re-lift pump with a pumping capacity of 1,500 gallons per minute along

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[108] This is intended to accommodate the time needed for morning startup and afternoon shutdown activities, and time for lunch breaks.

[109] That is, the pasture land being converted into biomass feedstock production is assumed to be abandoned rice land (during the 1980s/1990s), with the foundation irrigation infrastructure assumed to be intact and available, require only minor renovations.

[110] Although there are existing irrigation wells in the Middle Gulf Coast, Edna-Ganado, Texas area, discussion with Mickelson (2009) and Raun (2010) suggest substantial rehabilitation costs would be required to reactivate these wells in targeted expected HES production areas. Estimates for well refurbishment were obtained, but uncertainties regarding the degree of refurbishment required for the abandoned wells prompted the use of new well cost estimates.

with 15-inch poly pipe allows 3.3 acre-inches of water to be pumped per hour (Allen 2010).

Water wells can supply multiple fields because an open-canal system is used to transfer water over large distances. Therefore, per period pumping capacities are used to determine the number of irrigation wells that are needed (table D9). Multiple size irrigation wells (i.e., 2,000 gallon per minute (gpm), 2,500 gpm, and 3,000 gpm) are considered in this research. These different wells sizes determine the gallons of water that can be pumped per minute and delivered to fields for irrigation. Periodic pumping are calculated at a 90-percent operating efficiency to adjust for any down time due to maintenance and repairs or other unforseen shutdowns. The periodic pumping capacities including and between the April B and July B time periods are adjusted for additional loss of efficiency (i.e., + 30 percent) because it is assumed the water table will drop due to other simultaneous irrigation pumping requirements in the area (e.g., rice irrigation) that results in a total 30-percent loss in pumping capacity during these periods (Raun 2010).

HES is flood irrigated with 16.67 inches (i.e., two 8.3 acre-inch flood applications) of water per acre during the early weeks of the growing season to assure stand establishment and reduce yield variability (Blumenthal 2010). This management tactic is aimed towards guaranteeing the conversion facility with a constant, consistent, year-round supply of biomass feedstock.

The effects of not irrigating are difficult to quantify due to the fact that rainfall is unpredictable. Rooney (2010) and Blumenthal (2010) estimate that maximum yields for dryland HES in the Middle Gulf Coast, Edna-Ganado, Texas area would range between eight and 10 dry tons per acre, i.e., approximately 33 percent lower than that of irrigated HES. SG production is assumed to be dryland, i.e., with no irrigation.

To further demonstrate the need for irrigation of HES production in the Middle Gulf Coast, Edna-Ganado, Texas area, the maximum, minimum, and average monthly rainfall for a 25-year period for Wharton County, Texas are presented in figures D1 and D2. Since irrigation occurs after planting, the months of interest that correspond to Sorghasaurus'© planting and cultivation periods in the Middle Gulf Coast, Edna-Ganado, Texas area are February through June.

It is assumed that 40 percent of the irrigation water pumped (i.e., 6.67 of the total 16.67 acre-inches applied per acre) will be "lost" as a result of using an open-canal delivery system and furrow irrigation (Raun 2010; Falconer 2010). This magnitude of loss is largely due to evaporation and leaks in the open-canal system and percolation occurring during field flood irrigation as a result of the distance that the water must travel to reach the end of the rows. Thus, the total 16.67 inches of irrigation water used per acre are divided into two 8.3-inch applications, with an assured, realized, effective-applied rate of five acre-inches per acre per application (Rister 2010; Lacewell 2010). Both irrigation applications are on an as-needed basis, i.e., there may be some years in which rainfall is adequate and irrigation is not necessary.[111, 112]

[111] Nonetheless, the capital investments and associated annual ownership costs (including insurance, property taxes, and fixed repairs) of the irrigation wells and re-lift pumps are necessary to provide the capability of irrigation when it is necessary.

[112] Most probably, there would be years during which spring rainfall would be sufficient for HES stand establishment, thereby eliminating the need for irrigation. Discussion of such phenomena during the latter stages of this thesis research prompted a simplified sensitivity analysis (i.e., Scenario 9B) to investigate

The cost of a new irrigation well is divided into three main cost categories: (1) drilling, column, casing, and bowl; (2) engine; and (3) pump. Irrigation well cost information is presented in table D10. The average size well in the Middle Gulf Coast, Edna-Ganado, Texas area pumps 2,500 gallons per minute (gpm) (Raun 2010; Falconer 2009); this size well is used to provide irrigation water in the baseline scenario. The average irrigation well in the Middle Gulf Coast, Edna-Ganado, Texas area is drilled 500 to 800 feet deep, and it costs $200 to $225 per foot to drill and line with a 10" column and 20" casing. A depth of 800 feet and cost of $225 per foot was used to determine the drilling cost for a well, i.e., a total of $180,000 (Mickelson 2009; Raun 2010).

The engine size required for the irrigation well is dependent on its pumping capacity. A 200-horsepower engine is commonly used for a well size of 2,500 gpm and costs $23,000 (Mickelson 2009). This cost is adjusted by +/- 10 percent for well sizes one (i.e., 2,000 gpm) and three (i.e., 3,000 gpm) to reflect the different horsepower requirements and cost.[113]

the potential consequences of owning the irrigation wells but not using them (i.e., no pumping nor distribution of irrigation water during the year). The consequences of such ownership without using the wells were to lower the costs per dry ton of biomass feedstock from $134.01 to $124.92 and the cost per gallon of biofuel from $1.7867 to $1.6656 (tables E146-E149). The maximum rainfall during these periods ranges from 8.3 inches during February to 13 inches in June while the minimum rainfall ranges from zero inches during May to 0.4 inches during March and April. These levels and the range between them demonstrate the variability and unpredictable nature of rainfall in Wharton County. The average rainfall during these periods ranges from 2.8 inches during February to 4.9 inches during May. This suggest that, on average, rainfall alone will not supply enough water to guarantee the conversion facility with sufficient biomass feedstocks (Rooney 2010; Blumenthal 2010). Figure D2 reinforces this point by demonstrating in the majority of the years, that monthly rainfall will be less than five inches and frequently less than two inches.

[113] For irrigation well size one (2,000 gpm), the cost of the engine is decreased by 10 percent (i.e., to a cost of $20,700); and for irrigation well size three (3,000 gpm), the engine cost is increased by 10 percent (i.e., to a cost of $25,300).

The cost of the pumping unit for a 2,500 gpm well is $26,750, including the gearhead and flange (Mickelson 2009). This cost is adjusted in the same way as the engine cost to reflect the differences in the cost components among the three well sizes (Mickelson 2009)[114]. An extra 15 percent of the purchase price for each well size is added to the capital investment cost to account for having an inventory of extra parts on hand such as engines and pumps.

Fuel costs to operate the re-lift pump to distribute the irrigation water out of the lateral canal irrigation system were determined by multiplying the hourly fuel consumption rate by the fuel cost (Falconer 2009). The diesel price used for calculating per hour fuel cost was $2.05 per gallon (Producers Cooperative 2009). This calculation is then converted into a per acre-inch cost by dividing the hourly fuel cost by the acre-inches pumped per hour at the noted efficiency. Repair and maintenance costs for all irrigation wells are calculated as a percentage of the purchase price (Equation 10). It is assumed that cumulative repair and maintenance expenses are 100 percent of the purchase price over the 30-year life of an irrigation well (Falconer 2010) and an irrigation well pumps 7,000 acre-inches annually.

Equation 10. $$RM_{IW} = \left\langle \left[\left(IC \times RMC \right) \div UL \right] \div AU \right\rangle;$$

where,

RM_{IW} : repair and maintenance cost per acre-inch ($);

IC : initial cost of irrigation well including drilling and pump and gearhead ($);

[114] For irrigation well size one (2,000 gpm), the cost of the pumping unit is decreased by 10 percent (i.e., to a cost of $24,075), and for irrigation well size three (3,000 gpm), the cost of the pumping unit is increased by 10 percent (i.e., to a cost of $29,425).

RMC : repair and maintenance coefficient (%);

UL : expected useful life (years); and

AU : annual use (acre-inches).

The annual fixed maintenance cost rate for the irrigation wells is assumed to be one percent. This cost accounts for any minimal maintenance need to keep the wells in working condition during periods of little or no use (Rister 2010; Lacewell 2010). Insurance for the pump, gearhead, and power unit is not purchased for the irrigation wells (Rister 2010; Lacewell 2010).[115]

A total of 2,556.17 feet of poly pipe is required each year for each quarter section field size (i.e., 160 acres less allowance for turnrows, irrigation delivery laterals, etc. results in 150 acres of production). The pipe is used for one year and then discarded, being replaced the following year with new pipe on a different field[116]. The cost of 15" poly pipe is \$0.19 per foot (Nichols Irrigation 2009). The cost for poly pipe for one 150-acre field is \$486.06 or \$0.162 per acre-inch using 20 inches applied per acre.

[115] However, an extra 15 percent of the purchase price is added to account for having replacement parts on hand.

[116] Poly pipe is not reused because HES acreage is rotated on a one year in HES and two years out (fallow) basis; thus, the fields in production change every year and the labor and space required to collect and store the poly pipe and keep it in working condition would be excessive, not to mention the potential of damage to the poly pipe during its recovery and subsequent redeployment (Rister 2010; Lacewell 2010).

High-Energy Sorghum and Switchgrass Field Operations

High-Energy Sorghum

Field operations for HES are similar to those used for the production of various other row crops and consistent with the farming practices used in the Middle Gulf Coast, Edna-Ganado, Texas area (table D11) (Rooney 2010; Blumenthal 2010; Raun 2010; and Popp 2010). Since the primary land types used for HES production are assumed to be pasture and fallow rice land, several land preparation activities prior to planting are required to establish a level, well-developed seedbed. Discing is used to loosen the soil, knock down any rice levees and/or any other field unevenness, and incorporate residues into the soil. Land planing is then performed to level and prepare the field for the bedding operation Raun 2010)[117]. Rows are built by bedding and hipping the soil.[118, 119] Fertilizer is applied directly to the seedbed by using a fertilizer toolbar. The beds are then conditioned to break the soil crust and establish a level surface for planting. Only one cultivation is used because HES grows so quickly that it is unlikely there would be enough time to

[117] It is assumed these “extra” operations will be required each time a field comes back into production within the three-year rotation assumed for HES in this thesis research. That is, due to soil type and absence of field operations on a particular field during its two years out-of-production in the rotation, the field’s tilth and row structure must be reestablished prior to it being again suitable for planting (Raun 2010; Rister 2010; Lacewell 2010).

[118] “Bedding” (a.k.a. “listing” in some regions of the U.S.) refers to use of plow sweeps to form raised “beds” or mounds of soil in alternating linear geometric patterns across a field, with lowered middles, thereby forming raised elliptical surfaces, i.e., the beds. For Southern row-crop agricultural producers, the intent is to prepare their field such that there is (1) more surface area than available with a simple flat surface, allowing for more sunlight to be absorbed in early spring, facilitating earlier planting due to warmer soil conditions; (2) superior storage of sub-surface moisture, again favoring earlier planting due to adequate moisture availability for seed germination, and (3) improved drainage during excess moisture situations due to the lowered middles representing miniature drainage ditches from one end of the field to the other. This operation and the resulting “bed” facilitates furrow irrigation when fields are appropriately sloped from one end to the other (Rister 2010).

[119] “Hipping” refers to a field operation in which two pair of disk blades are used at an angle on each “bed” to lightly till and shape the bed without disturbing the sub-soil, thereby preserving any moisture therein (Rister 2010).

cultivate twice (Blumenthal (2010); Rooney (2010); Raun (2010); Popp (2010); and Falconer (2009)).

Switchgrass

SG field operations are broken down into two main categories: (1) establishment, and (2) production (table D12). All initial establishment operations are conducted by custom operators because SG is a perennial grass and it is expected the stand will have a life of 10 years (Huhnke 2009)[120]. Fertilizer and herbicides are also applied by custom operators on SG production acreage for harvest. Since pasture is the current main use of land, two discings are required initially to remove any residues, as heavy surface residues can provide a poor environment for SG seedling establishment. A herbicide is also applied to minimize weed competition during establishment. One field cultivation is then used to smooth the ground and prepare it for planting (Blade Energy Crops 2009).

Once SG is established, it is harvested by the corporate farm much like a conventional haying operation. A herbicide is annually applied to control weed pressure. Fertilizer is applied after the crop has been cut and baled to promote regrowth for subsequent harvest.

The costs noted above are considered a reasonable first step toward investigating the economics of SG biomass feedstock production in the targeted study area,

[120] Such an infrequent planting requirement is suggestive it is unnecessary/uneconomical to purchase drill-planting equipment. However, as subsequently noted in this thesis, Rooney (2011) suggests more frequent planting (i.e., a shorter life cycle) may be more appropriate for consideration in future economic analyses.

recognizing the dearth of available pragmatic data. Rooney (2011) notes several areas worthy of consideration for further investigation:

- There may frequently be a need to plant twice (or three times) to realize adequate/"good" SG stand establishment – if that is correct for the targeted study area, the calculated costs for providing biomass feedstocks to the conversion facility may be on the low side;
- It may be more appropriate to use a six-year life cycle (instead of the ten-year life cycle) assumed in this thesis research – if that is correct for the targeted study area, the calculated costs for providing biomass feedstocks to the conversion facility may be on the low side;
- The logistics of planting all of the requisite SG in the same year are suspect, especially given the intended reliance on custom operators – this is a production issue to be resolved, including incorporating insurance SG acreage into the rotation so that is used/cycled as well – more than likely, in actual practice, planting of SG would be phased in over time as allowed by availability of custom services, weather conditions, etc.;
- The assumption of year-round harvest is certain to be faulty – SG harvest should not be allowed during the initial spring regrowth periods (i.e., April and May) – such limitations would both increase costs of biomass feedstock

production and also preclude reliance on a year-round "Just-In-Time" delivery system dependent solely on HES and SG;[121] and

- Most probably, the current analyses do not properly account for lowered heat units available for field drying during fall and winter months, thus misrepresenting this aspect of SG harvesting. The consequences of such lengthened SG harvesting schedules are unknown without further investigation – the initial reaction is that more accurate portrayal of this phenomena would increase costs, but further reflection suggests a counter-lowering of costs may occur as harvesting capacities of machinery and equipment are increased as a result of their use being spread over longer periods.

Available Time Periods for Field Operations for High-Energy Sorghum

The periods during which each HES field operation may occur (table D13) represent reasonable times for performance of these operations, allowing for an orderly flow of land from the first operation to the last operation on each acre, with no adverse effects on harvested yields other than those represented in the planting/harvest period matrix (table D14). Within Sorghasaurus©, once a field operation has been performed on a given acre of land, that acre is made available for the next field operation to be performed

[121] The consequences of eliminating the April-May SG harvest periods while maintaining all other assumptions of the baseline scenario were investigated in Sensitivity Scenario 9C. Costs per dry ton of biomass feedstock were increased from $134.01 to $135.83 and the cost per gallon of biofuel increased from $1.7867 to $1.8111 (tables E150-E153). Additional issues of concern are noted in the Challenges, Limitations, and Future Research Needs section.

in the same or subsequent time period. Using this LP transfer technique, land is not allowed to have the same field operation performed twice, nor is it allowed to flow backwards into previous time periods or already-completed field operations. Available time periods for each operation are similar to those used for other row crops in the area (Popp 2010; Falconer 2009), with small adjustments made to accommodate the extra field operations that must take place to prepare pasture land for planting (Raun 2010).

Within the Sorghasaurus© linear programming model flow, the structure is such that the designated field operations are performed in the order declared in the data input section. Multiple operations on the same acre may occur within a period so long as

- those operations are all declared as possible in the period;
- adequate machinery, equipment, and labor resources are available in the period per the trafficable days assumption in effect; and
- all operations declared as required prior to such operations have been performed on such acreage.

High-Energy Sorghum and Switchgrass Harvest Yield Curves

<u>High-Energy Sorghum</u>

The harvest yield curve for HES is adapted from expert interviews with Texas AgriLife Research and Texas AgriLife Extension Service agronomists (Rooney 2010; Blumenthal 2010). Maximum yields for each planting/harvesting period combination are derived as a function of day length and ambient air temperature. A yield of 12 dry tons per acre is used as the baseline expected maximum harvested yield for the Middle Gulf Coast, Edna-

Ganado, Texas area. It is assumed the wet moisture content at harvest is dependant on the growth phase of the plant and the weather patterns during the production season. A wet harvest moisture content for an average year is assumed for each combination of planting/harvesting periods. The dry moisture content used in the base analysis is 15 percent.

Periods available for HES planting are assumed to be the same as for a sorghum crop planted for grain production in the Middle Gulf Coast, Edna-Ganado, Texas area (Blumenthal 2010; Popp 2010; Falconer 2010; Raun 2010). Harvest periods are set to allow for the harvesting operation to be spread out over several periods, allowing for determination of the most economic tradeoffs among machinery investment and harvested yields. The percent of maximum yield realized for each planting/harvest combination is subjectively determined by the growth phase of the plant and the length of time the plant has been growing (Blumenthal 2010). Lodging is a concern when growing and harvesting tall crops; thus, the last allowed harvest period for each planting date is set to avoid/minimize lodging (Blumenthal 2010).

Equation 11 is used to calculate the amount of wet tonnage harvested per period:

Equation 11. $$WY^{XY} = \left\langle MY^{X} \times \left[\left(1 - DMC^{XY}\right) \div \left(1 - WMC^{XY}\right)\right]\right\rangle;$$

where,

X : harvest period;

Y : planting period;

WY^{XY} : wet yield for HES planted during period X and harvested during period Y;

MY^{X} : maximum dry yield for HES planted during period X;

DMC^{XY} : dry moisture content of HES planted during period X and harvested during period Y; and

WMC^{XY} : wet moisture content of HES planted during period X and harvested during period Y.

For example, if the HES is planted in Feb B period and harvested in the Aug A period, then a maximum yield of nine dry tons per acre at 75 percent moisture content is expected (table D14). Using Equation 11 above and the assumed dry moisture content of 15 percent, the wet yield for the Feb B planting period and the Aug A harvest period is 30.6 wet tons[122]. The yield curves and corresponding harvesting and planting information for HES in the hypothetical Middle Gulf Coast, Edna-Ganado, Texas area are detailed in table D14.

Switchgrass

A maximum yield of three dry tons per acre is used as the baseline for estimating the dryland yield curve for SG (table A15) (Epplin 2009)[123]. Unlike HES that is green chopped, SG is cut and allowed to dry in the field until the moisture content reaches the

[122] {9 x [(1 - 0.15) / (1-0.75)]} = 30.6 wet tons

[123] A maximum yield of three dry tons per acre is assumed because SG is planted on pasture land which is assumed to be less productive than row crop land (Blumenthal 2010; Huhnke 2009).

desired level (i.e., 15 percent) and then baled;[124] thus, SG yield is expressed in dry tons. The SG yield curve estimates the yield for all time periods since SG is used as a supplemental biomass feedstock source and is harvested on an as-needed basis. It is assumed that overwintering SG (i.e., not harvested during Nov B to Mar A periods) results in a 25 percent dry matter loss from the maximum yield between these periods (Blade Energy Crops 2009). Thus, during the Nov B period, SG yield is discounted from the maximum of three dry tons per acre by five percent, during the Dec A and B periods the yield is discounted by 10 percent, during the Jan A and B periods the yield is discounted by 15 percent, during the Feb A and B periods the yield is discounted by 20 percent, and during the Mar A period the yield is discounted by 25 percent.

It is assumed that after the winter months (i.e., Nov B period through the Mar A period), SG yields will increase due to spring green up and the plant starting to regrow. To account for this, SG yields during the Mar B and Apr A periods are only discounted 20 percent. SG yields during the Apr B period are discounted 15 percent, SG yields during the May A periods are discounted 10 percent, and SG yields during the May B period are discounted five percent.[125]

The LP mechanics of Sorghasaurus'© in delivering an optimal solution are such that the distribution of SG harvesting may occur during non-peak yield periods. Factors accounting for such non-peak yield harvest periods include recognition of the

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[124] The tactic of allowing SG to dry in the field after being mowed is admittedly different than that assumed and previously described for HES. However, the volume of harvested SG with 3 dry ton maximum expected yields is substantially less than that of HES having 12 dry ton maximum expected yields, resulting in narrower "dry-down" time periods for SG than needed for HES.

[125] Attention is directed elsewhere where Rooney (2011) is noted as suggesting SG harvest should not be allowed during April-May or March-June.

competition for use of limited tractor, labor, and transportation resources for HES and SG harvest and preference for avoiding need of excessive investments in storage facilities inasmuch as SG can be harvested year-round (i.e., stored in the field in an unharvested state), among possibly other considerations. The SG yield distribution curve in table D15 reflects this phenomena, identifying (1) peak yield growth in Jun A through Nov A; (2) declining yields during Nov B through Mar A; and (3) increasing yields during Mar B through May B.

Variable Input Requirements for High-Energy Sorghum and Switchgrass

High-Energy Sorghum

The fertilizer nutrients requirements for HES are established with several assumptions: (1) fertilizer nutrients are applied at a rate of three parts nitrogen, one part phosphorus, and two parts potassium (Schulze 2010; McFarland 2010), and (2) 20 pounds of nitrogen per ton of biomass removed is sufficient (i.e., required) to realize yields of 12 dry tons per acre (Rooney 2010; Blumenthal 2010). Thus, the annual applied fertilizer nutrients rate for HES acreage is 240-40-160[126]. The fertilizer nutrients prices used in this application of Sorghasaurus© are \$0.35 per pound for nitrogen, \$0.45 per pound for phosphorus, and \$0.42 per pound for potassium (Falconer 2009). A herbicide is applied

[126] Development of the fertilizer budgets for HES (and, as subsequently presented, for SG) prompted consideration of the issue as to whether the fertility program should be tailored (1) to harvested yields (which are considered in this research to vary according to planting/harvest time periods combinations) or (2) to targeted, expected maximum yields. Observations of "real-world" phenomena regarding producers' propensity to manage for maximum yields and recognition that the yields designated in the HES (and SG) yield curves are approximations of what will be realized on average, but that it is not known with certainty how individual fields will "grow out" nor how field conditions existing at the times of planting and harvesting will affect exactly when individual fields are planted/harvested, it is assumed in this research that the fertility programs are defined for maximum-expected yields.

prior to planting to minimize weed competition and to ensure maximum establishment of the crop (Rooney 2010). Texas AgriLife Extension Service District 11 enterprise budgets (Falconer 2010) were used to determine the herbicide application rate, resulting in a $11.25 cost per acre. The planting rate is 80,000 seeds per acre (Rooney 2010). It is assumed that there are 12,000 HES seeds per pound and one pound of seed cost $5.00 (Blade Energy Crops 2010a, Rooney 2010, Blumenthal 2010). This calculation translates into seven pounds of seed applied per acre. Fertilizer, herbicide, and planting seed information for HES are provided in table D16.

Switchgrass

Fertilizer for SG is applied using the same three parts nitrogen, one part phosphorus, and two parts potassium ratio as that for HES (Schulze 2010; McFarland 2010). Nitrogen is not applied during the establishment year because SG seedlings have a slow growth rate and fertilizer would promote weed competition rather than SG growth (Blade Energy Crops 2009). During production years, nitrogen fertilizer nutrients are applied at a rate 20 pounds of nitrogen per ton of biomass removed. Since, it is assumed that the maximum yield is three dry tons per acre, 60 pounds of nitrogen is applied per acre, along with 20 pounds of phosphorus and 40 pounds of potassium (McFarland 2010). A broad-spectrum herbicide such as Roundup© is used during establishment, while 2, 4-D Amine is used annually following establishment to control broad-leaf weeds (Blade Energy Crops 2009) (table D17).

Transportation

High-Energy Sorghum

Semi trucks and end-dump semi trailers are used to transport harvested HES biomass feedstock to the conversion facility. The semi trucks are parked at the edge of the field and loaded by the in-field buggies which transport the HES from the harvesters. The amount of material one trailer can haul is dependant on the density of the harvested material, state and local legal restrictions, and capacity of the trailer. Since a yield growth curve is used in this analysis and the wet moisture content is not consistent for all of the harvested material, an average moisture content for each harvesting period is used to determine the density of the harvested biomass feedstock (table D18). Liberally interpreting Turhollow et al. (1996), an assumption is made that there is a linear relationship between the density and the moisture content.

The maximum legal total gross weight in Texas for a truck and trailer combination loaded with material is 80,000 pounds; however, the Texas Department of Transportation (TxDOT) provides permits that allows this weight limit to be exceeded. The permit required is the Non-Agricultural "Over Axle and Over Gross Weight Tolerance Permit." A Non-Agricultural permit is required because TxDOT considers silage to be a Non-Agricultural commodity since it is a processed product (TxDOT 2010). This permit allows users to exceed the maximum legal gross weight by five percent and the maximum legal axle weight by 10 percent and also allows the full weight to be transported on Farm to Market roads. Assuming this permit is acquired, a total legal gross weight of 84,000 pounds is used in this analysis. An "Over Axle and Over Gross Weight Tolerance Permit Bond" in the amount of $15,000 annually is also required to obtain this permit (TxDOT 2010).[127]

The truck and trailer combination weigh 37,700 pounds unloaded, leaving 46,300 pounds or 23.15 tons available for HES material. The capacity of the end-dump semi trailer is limited to 2,403 cubic feet, i.e., 40 feet long by 8.5 feet wide by 8.6 feet high (Nordstrom 2010)[128]. As the capacity of the trailer increases, so does the potential weight load; thus, there is a tradeoff between increased trailer capacity and legal gross weight. The end-dump semi trailer used in this analysis allows more cubic feet of material to be hauled when the density of the biomass feedstock is low because trailer capacity is not a restricting factor. It is assumed that the trailer is loaded at a 95 percent efficiency rate, meaning, that on average, only 43,985 pounds, or 2,283 cubic feet of material is hauled per trip.

To calculate the time it takes for one semi truck to make one full trip, the load time, travel time, and unloading time must be estimated. It takes a total of 33 minutes to load one end-dump semi trailer, since the semi trailers are loaded by the in-field buggies. This assumption is made because it takes 13.5 minutes to load one buggy and three minutes to dump. As one buggy leaves the harvester to travel to the edge of the field to dump, another buggy is ready to take its place and be loaded. As the loaded buggy reaches the end-dump semi trailer, it is assumed the next buggy is fully loaded by the

[127] One such permit is required for the corporate entity, it being sufficient for all the semi trucks and semi trailers operated by the corporate farm.
[128] This trailer is a Clement Monster end dump (Nordstrom 2010).

harvester and traveling to dump. The steady stream of buggies traveling from the harvester to the semi trailers allows little time to be lost between buggy dumps. The in-field buggies have a maximum capacity of 15 tons; therefore, two buggies are required to load one end-dump semi trailer to full capacity. Since two in-field buggies are required per semi truck load, it takes 27 minutes of travel time (for two buggies) from the harvester to the semi trailer and six minutes (for two buggies) to dump, totaling a load time of 33 minutes for one end-dump semi trailer.

The average one-way transporting distance from the field to the conversion facility is assumed to be 21.2132 miles (i.e., the middle point within the 30 mile radius)[129]. The average speed of the semi trucks is assumed to be 35 miles per hour to account for traffic and because a large portion of the travel time is on the farm and farm-to market roads. Using these two assumptions, it takes one hour and 21 minutes for one semi to travel from the field to storage or the conversion facility and back to the field to be loaded again.

It is assumed it takes 20 minutes for the end-dump semi trailer to be unloaded at the storage facility (which is assumed located near the conversion plant) and be ready to travel back to the fields. To account for refueling, any breakdowns, and other unanticipated delays that might occur, a "slippage" efficiency factor of 110 percent is

[129] The area of a circle is calculated as $A_1=\Pi r_1^2$, where A_1 is the area of the total circle in which HES and SG production may occur, Π is pi, and r is the radius of the circle. To determine the average distance from the center of the circle such that one-half of the circle's area is further than that average distance from the center and the other one-half of the area is closer than that average distance, the radius of a circle having one-half the area of A_1 must be determined. That is, solve $A_2=0.5*A_1=\Pi r_2^2$ for r_2. In the case of this thesis research, $A_1=3.14159265 * 30^2 = 2{,}827.43$ mi^2. For $A_2=0.5 * 2{,}827.43 = 1{,}413.715$ mi^2 = $3.14159265\ r_2^2$, $r_2^2 = 450.00$; taking the square root of 450.00 results in a radius (i.e., r_2^2) of 21.2132 miles.

used[130]. Using these assumptions, a round-trip haul time of two hours and 19 minutes per load is calculated. Equation 12 is a detailed account of the calculations:

Equation 12. $$HT = \left\langle \left[\left(\left((AD \times 2) \div MPH \right) \times 60 \right) + LT + UT \right] \times (E_{ST}) \right\rangle;$$

where,

HT : haul time (minutes);

AD : average one-way transporting distance (miles);

MPH : average speed (miles per hour);

LT : load time (minutes);

UT : unload time (minutes); and

E_{ST} : efficiency factor for semi trucks (%).

<u>Switchgrass</u>

Transporting SG to the conversion facility requires a flatbed trailer because the SG is ”square” baled with each bale being three feet high by four feet wide by eight feet long. A drop deck trailer is used to maintain the legal height limit of 14 feet, since the “square” bales are three feet high and a standard trailer (i.e., non-drop deck trailer) is between three and four feet off the ground[131]. The trailer used is 53 feet long and 8.5 feet wide; thus, a total of 42 “square” bales can be transported in one load if they are stacked three high.

[130] Ten percent more time is added to the total haul time per load to account for such slippage factors.
[131] To maximize load potential and allow the “square” bales to be stacked three high (totaling 9 feet), a drop deck trailer is used.

The average one-way transporting distance to the conversion facility and the average speed for SG transportation are assumed to be the same as that for HES. Thus, the average one-way transporting distance is 21.2132 miles and the average speed is 35 miles per hour. Pre-stacking the SG "square" bales at the side of the field reduces loading time. It is assumed it takes 45 minutes to load one trailer at the field and 40 minutes to unload one trailer at the conversion facility[132]. Using equation 12 above for HES, a total haul time of two hours and 53 minutes is calculated for one load of SG.

Transportation costs for HES, SG, and transported alternative biomass feedstocks are presented in table D19. The assumption is made that the flatbed trailer used for transporting SG has the same operating cost parameters as the trailer used for HES and transporting alternative biomass feedstocks. The salvage value for the truck and trailer were adapted from a U.S. Environmental Protection Agency (2009) study. The salvage value used was divided by the purchase price to determine the salvage value as a percentage of purchase price. This percentage was then multiplied by the purchase prices obtained from Bryan Freightliner (2009) and Nordstrom (2010) to obtain the salvage values for the semi trucks and semi trailers used in this analyses.

It is assumed there is a 15 percent probability for the truck and a five percent probability for the trailer an incident will occur that results in the company having to pay the insurance deductible for a major maintenance repair during the course of annual operations. Possible maintenance repair costs include replacing the engine or

[132] Unloading time is less than loading time because it is assumed the hay squeeze will travel less distance from the trailer to where the bales are stacked and stored. The hay squeeze can load 42 bales in 35 minutes, but it is assumed that it will take an extra 10 minutes to tie down the load when loading and an extra five minutes to untie the load when unloading.

transmission, or repairs due to an accident. The annual costs of this major maintenance

$$PM_T = \left[(FC \div MPG) + (OC \div MPC) + (TC \div MPT_{DDT}) + (STC \div MPT_{ST}) + (RM + M) \right];$$

repair are assumed to be $650 for the truck and $100 for the trailer (Neystel 2010). The costs of the "Over Axle and Over Gross Weight Tolerance" permit and bond are $255 and $150 for the truck and trailer, respectively (TxDOT 2010). It is assumed that front "steering" tires will wear out faster than the drive and trailer tires due to their turning and grinding of the tires against pavement. The tires for the truck and trailer cost $300 per tire (Petro Shopping Centers 2009). To account for any unexpected miscellaneous costs that occur during operation, $0.03 and $0.01 per mile are added to the truck and trailer operating costs, respectively. These costs may include traffic tickets and/or damages done to private property while traveling to the storage or the conversion facility (e.g., running over mailboxes).

Using equation 13, the per mile operating cost for a semi truck and trailer are calculated:

Equation 13.

where,

$_T$:	represents truck and trailer unit;
PM_T :	per mile operating costs ($);
FC :	fuel cost ($);
MPG :	miles per gallon (mpg);
OC :	cost of oil change ($);

MPC : miles per oil change (miles);

TC : drive and trailer tire cost ($);

MPT_{DTT} : miles per set of tires for drive and trailer tires (miles);

STC : steering tire cost ($);

MPT_{ST} : miles per set of tires for steering tires (miles);

RM : repair and maintenance ($); and

M : miscellaneous cost ($).

Equation 14 uses the results from equation 13 to calculate the hourly operating cost for transportation:

Equation 14.

where,

$_T$: represents truck and trailer unit;

HC_T : hourly operating cost for transportation ($);

PM_T : per mile operating cost ($);

AD : average distance (miles);

AS : average speed (miles per hour);

LT : load time (minutes);

UT :

$$HC_T = \left\langle \left[\left(\left(PM_T \times AD \right) \div \left(\left(\left(\left(AD \div AS \right) \div 60 \right) + LT + UT \right) \times \left(\left(1 - E_T \right) + 1 \right) \right) \times 60 \right) \right] \right\rangle;$$

unload time (minutes); and

E_T : efficiency factor (%).

Storage Operations

Recall that the driving force responsible for the CBFFE's existence is the need to supply a 30-million gallon conversion facility year-round with its biomass feedstock requirements either from HES and/or SG plus possibly some purchased alternative biomass feedstocks. The less-than-year-round harvesting period for HES necessarily introduces the possible requirement of storage facilities to allow for the accumulation of biomass feedstock inventory during the harvesting season and its subsequent use thereafter. That is, during periods when HES is not delivered "Just-In-Time" to the conversion facility, it can be stored as silage in a concrete bunker. A storage degradation factor of approximately one percent per two-week period is used to account for any loss of quality and quantity occurring during storage (Rooney 2010; Blumenthal 2010). Each storage bunker is 320 feet long, 64 feet wide, and 12 feet high and has a capacity of 245,760 cubic feet each. Allowing for an average density of 28.60 pounds per cubic foot for HES during the July A period, one bunker can hold 3,514 tons of biomass feedstock, equivalent to about three days of the conversion facility's biomass feedstock requirements during the July A period.

Wheel loaders are used to assist in unloading the semi trailers containing HES green chop silage at the storage site and to pack down the silage for storage[133]. Once full, the bunkers are covered with a plastic film to minimize storage losses by reducing microbial growth and the amount of rain available to penetrate the surface. It is assumed

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[133] A wheel loader is a piece of machinery often used in construction to load material.

a roller is attached to the bunker and used to assist in unrolling the plastic film and covering the biomass feedstock. An extra $1,000 is added to the bunker cost to account for this roller.[134]

The storage bunkers are located in close proximity to the conversion facility to minimize handling time and cost. Once the HES is unloaded and stored, it becomes the responsibility of the conversion facility to transfer the biomass feedstock from storage to processing. The conversion facility is also responsible for removing any moisture in excess of the 15 percent level considered desirable for conversion activities. Also, the environmental consequences and cost aspects of disposing of such excess moisture are not considered in this thesis research.[135]

The bunkers are constructed in concrete sections, allowing any size bunker to be used. The concrete panels are eight feet long by 12 feet high and cost $1,200 each. The chosen size of the bunkers used in this research is 320 feet by 64 feet, thus, requiring 88 concrete panels to be used for each bunker. This size bunker was chosen to allow for easy access by the unloading semi trucks. The land required for one bunker is assumed to be double the square footage of its base, allowing for extra space to maneuver the semi

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[134] $1,000 is an subjective estimate of the cost of this type of roller (Rister 2010).

[135] As noted throughout this thesis, the principal objective of this research is to identify the logistics cost of delivering a year-round supply of HES feedstock, possibly supplemented by SG, to a biomass conversion facility. No attempt is made to estimate the conversion costs associated with the facility, including any reflection of how the feedstocks will be prepared/dried prior to conversion. Admittedly, these costs could be substantial, further reflecting the angst associated with use of high moisture feedstocks. Recognizing that 33,334 tons of dry feedstocks are needed each month by the conversion facility and assuming an average 70 percent incoming moisture of such feedstocks (if all are HES),15,278,083 gallons of excess moisture need to be removed each month, equivalent to 46 acre-feet of water. Management of such excess moisture disposal is dependent on its method of removal, but could require construction of evaporation ponds or other disposal means.

trucks. Insurance is not considered as an expense for the silo bunkers because they are not considered to be structural[136]. Storage bunker information can be found in table D20.

Cellulosic Conversion Facility Biomass Feedstock Requirements

A 30-million gallon per year conversion facility is assumed in this research for purposes of illustrating the periodic biomass feedstock requirements feature of Sorghasaurus©. It is assumed that the conversion facility operates 24 hours a day and 365 days per year[137]. The conversion efficiency for HES is assumed to be 75 gallons per dry ton at 15 percent moisture content (Avant 2009). Thus, a total of 400,000 dry tons of biomass, net of any storage losses incurred, must be delivered to the conversion facility annually to meet these requirements. Total annual supply is broken down into per period biomass feedstock requirements to accommodate the bi-weekly nature of Sorghasaurus©. Dry ton requirements per hour are obtained by dividing total annual supply (i.e., 400,000 dry tons) by the total operational hours per year. Days per bi-weekly period are then multiplied by per hour dry ton requirements to determine periodic biomass feedstock requirements (table D21).

[136] Further, the biomass feedstock is not insured by the CBFFE while in storage because it is considered the property of the conversion facility once it is stored. Whether the conversion facility insures the biomass feedstock or not is its decision.

[137] Such year-round operating assumptions ignores the possibility of one or more scheduled extended period(s) of downtime for maintenance, e.g., two weeks during June prior to harvest of new crop HES. The stated assumption presumes that required maintenance is a continual operation, precluding the need for shutdown of the total facility. If such shutdowns are to be a normal course of the facility's operations protocol, the biomass feedstock needs identified in this research are "somewhat" excessive, resulting in "somewhat" of a larger CBFFE being constructed than is necessary. With this possibility recognized, however, the effects of reducing the biomass feedstock needs by 5-10 percent on the cost per ton of delivered biomass feedstock (i.e., the targeted measurement standard in this research) are expected to be minimal due to economies of size realized in the CBFFE identified in this research.

Overhead Management and Support Staff

The role of overhead management is to oversee the operations and guarantee that tasks are performed in the appropriate manner. The assumed management structure for the CBFFE is presented in exhibit D1.

The CEO is responsible for overseeing the entire operation. The VP of Operations is responsible for acquiring alternative biomass feedstocks if HES or SG biomass feedstocks are not available and overseeing the logistics and operations coordinators. The main role of the VP of operations is to guarantee that the conversion facility is always supplied with biomass feedstocks in the most efficient manner. The VP of Finance is responsible for the accountants and assuring that the CBFFE booking is accurate and up to date.

The logistics and operations coordinators are the overall decision makers for the transportation and production operations, respectively. They decide when field operations will occur and coordinate the transportation trucks so there is an orderly flow of trucks transporting biomass feedstocks to the conversion facility.

Field staff and logistics supervisors report any problems or concerns to the logistics and operations coordinators. The field staff are responsible for machinery equipment operators while the logistics supervisors are responsible for transport drivers. One field staff employee and one logistics supervisor will be hired for every five machinery and equipment operators and every five transport drivers. Overhead management labor structure and costs for a 30-million gallon/year conversion facility are provided in table D22.

Baseline Scenario Data Summary

The data described in this appendix provides the information used to apply the model for the baseline scenario and subsequent sensitivity analyses scenarios. HES and SG are the only biomass feedstock sources considered in the baseline scenario while HES monoculture and SG monoculture systems are used in sensitivity analyses for comparison. The following bulleted list provides a capsulated glimpse of the basic assumptions imposed on the baseline scenario:

- A cost-minimization approach is applied to all activities comprising the holistic production-harvesting-transportation-storage supply chain system;

- The objective is to minimize the cost of supplying a 30-million gallon biomass conversion facility with its necessary biomass feedstocks using HES and SG sources, assuming 75 gallon of biofuels are produced per dry ton of biomass feedstock;

- The targeted production area is the Texas Middle Gulf Coast, within a 30-mile radius of Edna-Ganado located along U.S. Highway 59;

- One sole, corporate farming entity is responsible for all production, harvesting, transportation, and storage activities;

- All farmed HES and SG acreage is leased from landowner; acreage is currently pasture originating from rice production acreage abandoned during 1980s and 1990s;

- HES is on a one-year-in, two-years-out rotation; three acres are leased for every one acre planted; rotation acreage is sub-leased to others for pasture; the net lease cost per planted acre is $57.50, including an incentive payment;

- SG is established via custom operations; it has a ten-year expected life; annual lease rate is $22.50 per acre;

- An additional 40,000 acres of land is leased for SG insurance (equivalent to approximately 25 percent of the annual conversion facility's needs);

- All machinery and equipment are purchased, excluding that needed to establish SG acreage, including requisite semi trucks and semi trailers for transporting biomass feedstocks to conversion facility;

- There is an unlimited supply of full-time labor available for hire;

- Part-time labor is available only during the July A - November B HES harvest periods and is restricted to 39 laborers;

- HES is irrigated with 16.67 acre-inches of water per planted acre; refurbishing/development of associated 2,500 gpm irrigation wells is treated as capital cost;

- SG is restricted to 100,000 dry tons (equivalent to approximately 25 percent of the annual conversion facility's needs);

- 12 dry ton per acre is the maximum-expected HES yield;

- 3 dry ton per acre is the maximum-expected SG yield;

- Dry HES and SG are considered equivalent for conversion efficiency purposes;

- An extra production equivalent to three periods of biomass feedstock needs/inventory were produced in year one; the baseline scenario values used for comparison purposes are year two results, not including the production of this extra inventory;

- A one percent periodic storage loss factor occurs in the feedstock (HES and SG);

- Annual biomass feedstock requirements of the conversion facility are set at 400,000 dry tons; distributed equally (based on a daily rate) among 24 periods, each consisting of 14-15.5 days;

- HES is transported on a wet-basis;

- SG is transported on a dry-basis;

- Fertilizer nutrients are applied at a ratio of 3-1-2 for N-P-K per expected ton of biomass yield and 20 pounds of nitrogen is applied per dry ton of biomass expected to be removed (i.e., 240N-80P-160K for expected 12 tons per acre of HES and 60-20-40 for expected 3 tons per acre of SG);

- Dry moisture content is assumed to be 15 percent;

- Trafficable days are set at a 75 percent probability level;

- Field transporting and road transport to storage facility located adjacent to front gate of conversion facility must occur on same day of harvest, i.e., there is no decentralized intermediate storage;

- Wet HES biomass feedstock is assumed converted to dry at storage for the conversion facility's needs, but costs of doing so are ignored;

- HES harvested yields vary according to model-user-specified relationships among planting/harvest period combinations, with moisture content also varying; and

- SG harvested yields vary according to model-user-specified relationship for harvest periods, with moisture content assumed to be dry 15 percent.

Table D1. Corporate Farm Headquarters Cost for High-Energy Sorghum and Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Purchase Price ($/sq-ft)	Expected Useful Life (years)	Salvage Value ($/sq-ft)	Annual Fixed Maintenance Cost Rate per $100 of Initial Cost ($/sq-ft)	Annual Fixed Insurance Cost ($/yr)	Annual Fixed Property Tax Rate per $100 of Initial Cost (%)	Annuity Equivalent Cost of Ownership ($/sq-ft)[a]
Land for Headquarters	$ 0.11[b]	30[c]	$ 0.11[d]	$ 0.00	$ 0.00	$ 2.75[e]	$ 0.02
Office Space	150.00	30	0.00	1.00	1.50	2.75	26.36
Road Base	0.92	10	0.00	5.00	0.00	2.75	0.10
Pole Barn	14.00	30	0.00	1.00	0.14	2.75	2.46
Barn for Inside Machinery Storage	120.00	30	0.00	1.00	1.20	2.75	21.09

Source: Sturdivant (2010); Neystel (2010); Rister (2010).

[a] Annualized ownership costs accounting for asset loss of value over its useful life, insurance, property taxes, fixed repairs, and opportunity cost of investment (Rister et al. 2009), using the assets' respective useful lives and a capital discount rate of 5.75 percent (Rister 2010; Lacewell 2010).
[b] Equivalent to $4,792 per acre.
[c] All headquarter items' useful lives are designated as 30 years (except for 10 years for the road base) to provide for a conservative evaluation time frame.
[d] There is no assumed appreciation or depreciation in value for the headquarters. If there is any appreciation that does occur, it is assumed that such appreciation is consumed by salvaging of the property and returning it to a salable state at the end of the planning horizon (Rister 2010; Lacewell 2010).
[e] Rister (2010).

Table D2. Space Required for Machinery and Implement Storage for High-Energy Sorghum and Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Width x Length (ft)	Space needed for Storage (sq -ft)[a]	Space Inflation Factor[b]	Total Space needed for Storage (sq -ft)
Tractor Size 1	10 x 20	200	1.2	240
Tractor Size 2	9.4 x 16.8	157	1.2	189
Tractor Size 3	7.7 x 14.7	113	1.2	136
Tractor Size 4	6.7 x 11.6	78	1.2	94
Planter	23.8 x 15	357	1.2	428
Harvester Header	15 x 20 19 x 7	433	1.2	520
In-Field Buggy	10 x 20	200	1.2	240
Transport Trucks	8 x 20	160	1.2	192
Support Vehicles	8 x 15	120	1.2	144
Storage Handling	9.7 x 25.5	247	1.2	297
Disc	26 x 15	390	1.2	468
Bedder	38 x 10	380	1.2	456
Fertilizer toolbar	38 x 10	380	1.2	456
Cultivator	38 x 10	380	1.2	456
Sprayer	14.1 x 24	338	1.2	406
Hay Cutter Header	8 x 15 16 x 8	248	1.2	298
Wheel Rake	7 x 18	126	1.2	151
“Square” Baler	8.5 x 24	204	1.2	245
Hipper	38 x 10	380	1.2	456
Rolling Conditioner	38 x 8	304	1.2	365
Land Plane	12 x 60	720	1.2	864
Bale Wagon	10.7 x 33.1	335	1.2	402
Hay Squeeze	9.7 x 25.5	247	1.2	297

Source: John Deere (2009); Horstline Equipment (2009); Falconer (2009); Purdy (2010); Kelly Manufacturing Company (2010); New Holland (2010); Heavey (2010) and own modifications.

[a] Space needed for storage is determined as length multiplied by width of equipment.

[b] Space inflation factor is used to account for extra space between equipment.

Table D3. Rent for Land Resources for Planting of High-Energy Sorghum and Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Land Type	Maximum Available Acres for Lease[a]	Base Cash Rent ($/acre)[b]	Incentive Payments[c]	Base Income for Re-Leasing Land ($/acre)[d]	Total Net Cash Lease ($ planted/acre)[e]
High-Energy Sorghum		$45.00	$22.50	$10.00	$57.50
Switchgrass Production Land	271,433	15.00	7.50	n/a[f]	22.50
Switchgrass Insurance Land		15.00	7.50	5.00	17.50

Source: Popp (2010); Raun (2010); and own modifications.
[a] This represents all of the land available for lease within a 30-mile radius of the conversion facility, i.e., is 15 percent of 1,809,555 acres.
[b] Since HES is in a three-year rotation, three acres of land are rented to realize one planted acre; thus, base cash rent is determined as $15.00 times three acres. SG is not rotated; therefore, one acre is cash rented to obtain one planted acre.
[c] An incentive payment of 50 percent of base cash rent is used as an incentive to the landowner.
[d] In the two years that HES is not produced on a given acre, the land is subleased at a rate of $5.00 per acre.
[e] Equivalent to base cash rent plus incentive payment less base income for re-leasing land.
[f] n/a: not applicable.

Table D4. Specified Field Operations, Tractor and Equipment Complements, and Capacities for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Tractor Size 1	Tractor Size 2	Planter	In-Field Buggy	Disc	Bedder	Fertilizer Toolbar	Cultivator	Hipper	Rolling Conditioner	Self-Propelled Sprayer	Harvester	Land Plane	Assumed Operating Efficiency	Machinery Capacities at Stated Efficiency
Field Operations	225hp	152hp	12R - 38"	15 ton	26'	------------------12R - 38"------------------				26'	90'	6 Row	18'W x 60'L	%	acres/hour[a]
Disc	X				X									80	12.60
Land Plane	X												X	80	6.98
Bed	X					X								80	20.27
Hip Rows	X								X					80	20.27
Fertilize	X						X							65	14.97
Spray											X			65	56.73
Knock Down Beds		X								X				80	13.87
Plant	X		X											65	13.47
Cultivate		X						X						80	18.42
Harvest															
Harvester												X		80	4.61
In-Field Buggy	X	X		X										80	n/a [b]

Source: Popp (2010); Raun (2010); Falconer (2010).

[a] Machinery capacities are determined by the speed, width, and effective capacity of the least-cost combination (Bowers 1975).

[b] n/a: not applicable.

Table D5. Storage Handling Equipment Effective Capacity for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Time Periods	Moisture Content of Harvested Feedstock (%)	Average Density of Harvested Feedstock (lbs/cu-ft)[a]	Effective Capacity (tons/hour)[b]
Jul A	75	28.6	37.07
Jul B	75	28.6	37.07
Aug A	75	28.6	37.07
Aug B	75	28.6	37.07
Sept A	75	28.6	37.07
Sept B	75	28.6	37.07
Oct A	75	28.6	37.07
Oct B	75	26.0	33.70
Nov A	65	23.4	30.33
Nov B	60	20.8	26.96

Sources: Sturdivant (2010); Turhollow et al. (1996).

[a] Densities are based on moisture content therefore they vary based on the harvest yield curve.

[b] Effective capacity based on bucket size, feedstock density, and bucket cycle time.

Table D6. Tractor and Equipment Complements, and Capacities for Switchgrass Production, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Tractor Size 3	Self-Propelled Bale Wagon	Hay Squeeze	Self-Propelled Hay Cutter	Rake	"Square" Baler	Self-Propelled Sprayer	Custom Fertilizer	Assumed Operating Efficiency	Machinery Capacities at Stated Efficiency[a]
Field Operations	110hp	10 bale load		16'	14 Wheel	3' x 4' Bales	90'	n/a	%	acres/hour[a]
Cut				X					80	8.70
Rake	X				X				80	16.00
"Square" Bale	X					X			80	7.21
Haul-and-Stack		X	X						n/a [b]	n/a
Spray							X		65	56.73
Fertilize								X	n/a	n/a

Source: Popp (2010); Raun (2010); Falconer (2010).

[a] Machinery capacities are determined by the speed, width, and effective capacity of the least-cost combination (Bowers 1975).

[b] n/a: not applicable.

Table D7. Machinery and Implement Capital Investment Costs and Associated Parameters for High-Energy Sorghum and Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Description	Purchase Price ($)	Expected Useful Life (years) [a]	Annual Use (hrs) [b]	Salvage Value ($) [c]
Tractor Size 1	225hp	$172,560	5	1,300	$60,396
Tractor Size 2	152hp	132,050	5	1,100	52,820
Tractor Size 3	110hp	68,298	10	1,650	27,319
Tractor Size 4	75 hp with loader	39,499	11	600	15,800
Planter	1720 Stack-Fold	65,884	2	850	6,588
Harvester	7550	369,613	4	850	58,442
In-Field Buggy	15 ton	36,500	7	850	9,125
Support Vehicles	3/4 ton	35,000	4	850	14,000
Storage Handling	JD 544K	123,025	8	800	49,210
Disc	650 Folding Disc	44,996	4	700	6,749
Bedder	12R-38"	19,900	16	150	2,985
Fertilizer toolbar	12R-38"	15,000	7	350	2,250
Cultivator	12R-38"	94,500	5	800	14,175
Sprayer	4730 SP	226,628	7	750	33,994
Hay Cutter	16ft	115,863	4	1600	40,552
Wheel Rake	14 Wheel	21,625	4	1200	3,244
“Square” Baler	5' x 6' bales	41,802	4	1500	6,270
Hipper	12R - 38"	23,905	7	350	3,586
Rolling Conditioner	26'	30,290	4	800	4,544
Land Plane	18'W * 60'L	39,500	4	500	5,925
Bale Wagon	10 bale load	145,432	4	1600	57,097
Hay Squeeze	3 bale load	136,525	4	1500	51,882

CONTINUED

Source: John Deere (2009); Horstline Equipment (2009); Falconer (2009); Purdy (2010); Kelly Manufacturing Company (2010); and own modifications.

[a] Determined by multiplying the annual use and useful life obtained from Falconer (2009) together, and then dividing by hours of annual use in the preliminary Sorghasaurus© analysis.

Table D7. (Continued)

Item	Annual Fixed Maintenance Cost per $100 of Initial Cost ($) [d]	Annual Fixed Insurance Cost Rate per $100 of Initial Cost ($) [e]	Hourly R&M Cost [f]	Hourly Fuel and Lube Cost [g]	Hourly Operating Cost [h]	Annuity Equivalent Cost of Ownership [i]
Tractor Size 1	$1.00	$0.60	$ 3.77	$ 27.35	$ 31.12	$ 33,038
Tractor Size 2	1.00	0.60	2.89	18.20	21.09	21,557
Tractor Size 3	1.00	0.60	1.49	12.74	14.24	14,750
Tractor Size 4	1.00	0.60	0.86	9.10	9.96	4,574
Planter	1.00	0.60	34.70	n/a	34.70	37,724
Harvester	1.00	0.60	77.87	42.44	120.30	91,129
In-Field Buggy	1.00	0.60	3.45	n/a[j]	3.45	5,779
Support Vehicles[k]	1.00	0.60	4.01	23.00	27.01	8,353
Storage Handling	1.00	0.60	2.69	26.31	29.00	16,568
Disc	1.00	0.60	13.17	n/a	13.17	12,445
Bedder	1.00	0.60	6.55	n/a	6.55	2,135
Fertilizer toolbar	1.00	0.60	4.94	n/a	4.94	2,672
Cultivator	1.00	0.60	19.91	n/a	19.91	22,361
Sprayer	1.00	0.60	34.10	7.07	41.17	39,782
Hay Cutter	1.00	0.60	19.28	28.29	47.57	27,254
Wheel Rake	1.00	0.60	4.02	n/a	4.02	6,416
Round Baler	1.00	0.60	1.63	n/a	1.63	16,559
Hipper	1.00	0.60	7.87	n/a	7.87	4,257
Rolling Conditioner	1.00	0.60	6.46	n/a	6.46	8,573
Land Plan	1.00	0.60	9.88	n/a	9.88	10,607
Bale Wagon	1.00	0.60	18.18	11.79	29.97	30,957
Hay Squeeze	1.00	0.60	2.99	26.31	29.30	27,101

Source: John Deere (2009); Horstline Equipment (2009); Falconer (2009); Purdy (2010); Kelly Manufacturing Company (2010); and own modifications.

[a] Determined by multiplying the annual use and useful life obtained from Falconer (2009) together, and then dividing by hours of annual use in the preliminary Sorghasaurus© analysis.

[b] Annual use was determined by solving Sorghasaurus© using the preliminary base data for the hypothetical Middle Gulf Coast, Edna-Ganado, Texas area Corporate Biomass Feedstock Farming Entity.

[c] Determined by using the salvage value coefficient obtained from Falconer (2009) enterprise budgets.

[d] Determined through conversations with Rister (2010); Lacewell (2010).

[e] Determined through conversations with Neystel (2010).

[f] Determined by using the repair and maintenance coefficient obtained from Falconer (2009) enterprise budgets.

[g] Determined by using the fuel consumption rate obtained from Falconer (2009) enterprise budgets.

[h] Hourly operating costs are calculated by adding hourly R&M cost and hourly fuel and lubrication cost.

[i] Annualized ownership costs accounting for asset loss of value over its useful life, insurance, property taxes, fixed repairs, and opportunity cost of investment (Rister et al. 2009), using the assets' respective useful lives and a capital discount rate of 5.75 percent (Rister 2010; Lacewell 2010).

[j] n/a: not applicable.

[k] Support vehicles are not considered an "implement of husbandry" (Texas Comptroller of Public Accounts 2006) and thus property taxes of 2.75 percent are accessed.

Table D8. Available Work Hours per Day, Feasible Time Periods, and Trafficable Days for Field Operations and Transportation for High-Energy Sorghum and Switchgrass Production in Sorghasaurus© Model, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Abbreviations for Time Periods in This Application of Model	Number of Days in Corresponding Period for This Application of Model	Day Lengths (rounded to the nearest Hour)	Daily Hours Available for Work	Trafficable Field Days @ 50%	Trafficable Field Days @ 75%	Trafficable Field Days @ 90%
Jun A	15	14	13	15.00	11.72	7.07
Jun B	15	14	13	12.71	7.93	4.13
Jul A	15	14	13	14.83	11.33	7.87
Jul B	16	14	13	16.00	13.60	10.06
Aug A	15	13	12	14.84	10.48	7.24
Aug B	16	13	12	13.77	8.48	3.68
Sept A	15	13	12	9.92	5.14	2.32
Sept B	15	12	11	8.05	3.23	1.56
Oct A	15	12	11	10.90	5.68	1.91
Oct B	16	11	10	14.42	7.10	2.77
Nov A	15	11	10	14.45	10.11	6.53
Nov B	15	10	9	14.66	10.17	7.08
Dec A	15	10	9	15.00	10.67	3.88
Dec B	16	10	9	16.00	11.09	9.71
Jan A	15	10	9	13.85	6.31	2.87
Jan B	16	10	9	16.00	12.33	7.18
Feb A	14	11	10	13.25	7.66	4.74
Feb B	14.25[a]	11	10	12.22	8.49	3.44
Mar A	15	11	10	13.94	11.64	6.91
Mar B	16	12	11	16.00	14.40	12.30
Apr A	15	12	11	15.00	12.42	9.46
Apr B	15	13	12	15.00	13.14	9.56
May A	15	13	12	14.98	11.13	7.61
May B	16	14	13	14.52	9.07	4.08

Source: Parker (1985); Bordovsky (1979).

[a] The 0.25 of a day represents averaging out" leap year" over four years.

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Table D8. (Continued).

Abbreviations for Time Periods in This Application of Model	Maximum Available Work Hours per Period @ 50%[b]	Maximum Available Work Hours per Period @ 75%[b]	Maximum Available Work Hours per Period @ 90%[b]	Hourly Additions to Labor from One Employee @ 50%[c]	Hourly Additions to Labor from One Employee @ 75%[c]	Hourly Additions to Labor from One Employee @ 90%[c]
Jun A	195.00	152.35	91.90	253.50	198.06	119.46
Jun B	165.18	103.03	53.64	214.73	133.94	69.74
Jul A	192.84	147.34	102.31	250.69	191.54	133.00
Jul B	208.00	176.75	130.80	270.40	229.77	170.04
Aug A	178.11	125.72	86.84	231.54	163.44	112.89
Aug B	165.27	101.77	44.19	214.86	132.30	57.45
Sept A	119.04	61.65	27.87	154.76	80.15	36.23
Sept B	88.56	35.57	17.18	115.13	46.24	22.34
Oct A	119.94	62.51	20.99	155.93	81.26	27.29
Oct B	144.20	70.97	27.65	187.46	92.26	35.95
Nov A	144.50	101.09	65.27	187.85	131.41	84.85
Nov B	131.94	91.53	63.76	171.52	118.99	82.89
Dec A	135.00	96.02	34.96	175.50	124.82	45.45
Dec B	144.00	99.82	87.41	187.20	129.76	113.63
Jan A	124.65	56.76	25.83	162.05	73.79	33.58
Jan B	144.00	111.00	64.63	187.20	144.29	84.02
Feb A	132.50	76.63	47.41	172.25	99.62	61.64
Feb B	122.20	84.86	34.44	158.86	110.32	44.77
Mar A	139.40	116.37	69.08	181.22	151.28	89.81
Mar B	176.00	158.44	135.35	228.80	205.97	175.95
Apr A	165.00	136.66	104.06	214.50	177.65	135.28
Apr B	180.00	157.64	114.67	234.00	204.93	149.07
May A	179.81	133.60	91.30	233.75	173.68	118.69
May B	188.71	117.85	53.08	245.32	153.21	69.00

Source: Parker (1985); Bordovsky (1979).

[b] Maximum available work hours per period are determine by multiplying trafficable days per period by the number of work hours per day.

[c] Hourly additions to labor from one employee are determine by multiplying maximum available work hours per period by 1.3., with the 1.3 representing a labor adjustment factor of 30 percent is added to account for any additional time needed for fueling, repairs, and transporting machinery between fields.

Table D9. Irrigation Well Periodic Pumping and Re-Lift Pump Capacities for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Time Periods	Groundwater Well Size 1: 2,000 gpm[a] (acre-inches)	Groundwater Well Size 2: 2,500 gpm[a] (acre-inches)	Groundwater Well Size 3: 3,000 gpm[a] (acre-inches)	Re-lift Pump: 1,500 gpm
Jun A [b]	1,324	1,656	1,987	993
Jun B [b]	1,289	1,611	1,933	993
Jul A [b]	1,217	1,521	1,826	993
Jul B [b]	1,069	1,336	1,604	1,060
Aug A	1,432	1,790	2,148	993
Aug B	1,527	1,909	2,291	1,060
Sept A	1,432	1,790	2,148	993
Sept B	1,432	1,790	2,148	993
Oct A	1,432	1,790	2,148	993
Oct B	1,527	1,909	2,291	1,060
Nov A	1,432	1,790	2,148	993
Nov B	1,432	1,790	2,148	993
Dec A	1,432	1,790	2,148	993
Dec B	1,527	1,909	2,291	1,060
Jan A	1,432	1,790	2,148	993
Jan B	1,527	1,909	2,291	1,060
Feb A	1,336	1,671	2,005	927
Feb B	1,360	1,700	2,040	944
Mar A	1,432	1,790	2,148	993
Mar B	1,527	1,909	2,291	1,060
Apr A	1,432	1,790	2,148	993
Apr B [b]	1,370	1,713	2,056	993
May A [b]	1,360	1,700	2,040	993
May B [b]	1,436	1,795	2,154	1,060

[a] Periodic pumping capacities are expressed in acre-inches per period, with decimal values truncated in this table, but not in the model calculations. These capacities are found by multiplying the per day acre-inch pumping capacity at 90 percent efficiency for each well by the number of days in each period. For example, for a 2,000 gpm in the Mar A time period, 15 days is multiplied by 119.32 acre-inches per day to determine that 1,789.77 acre-inches can be pumped during this period.

[b] The pumping capacities during these periods are adjusted for an additional 30 percent loss in efficiency due to a lower water table resulting from other simultaneous irrigation pumping occurring in the area, e.g., rice irrigation (Raun 2010).

Table D10. Groundwater Well Capital and Operating Costs for High-Energy Sorghum Irrigation, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Groundwater Well Size 1: 2,000 gpm	Groundwater Well Size 2: 2,500 gpm	Groundwater Well Size 3: 3,000 gpm	Relift Pump: 1,500 gpm
Maximum Number of Wells Available[a]	0	250	0	n/a
Purchase Price-New ($)	258,491	264,213	269,934	17,250
Expected Useful Life (years)	30	30	30	20
Salvage Value ($)	0.00	0.00	0.00	0.00
Acre-Inches Pumped per Hour at 90% efficiency[b] (ac-in)	3.9	4.9	5.9	2.9
Fuel Use per Hour (gallons)	8.0	8.5	9.0	0.8
Assumed Annual Use (ac-in)	7,000	7,000	7,000	7,000
Operating Cost per Acre-Inch				
Fuel Cost per Acre-Inch ($)	4.12	3.50	3.09	0.55
R&M per Acre-Inch ($)	1.23	1.26	1.29	0.12
Total per Acre-Inch Operating Costs ($)	5.35	4.76	4.38	0.67
Annual Fixed Maintenance Cost[c]	2,585	2,642	2,699	173
Annual Fixed Insurance Cost[d] ($)	0.00	0.00	0.00	0.00
Annual Fixed Property Tax Rate[e] ($)	0.00	0.00	0.00	0.00
Poly Pipe Cost per Acre-Inch ($)				0.15
Annuity Equivalent Cost of Ownership[f] ($)	20,864	21,326	21,788	1,646

Source: Falconer (2009); Mickelson (2009).

[a] In the baseline application, only well size two is considered

[b] The equation for calculating acre-inches pumped per hour is: {[(gpm x 60) / gallon per acre inch)] x efficiency}.

[c] Annual fixed maintenance cost is calculated as one percent of the purchase price (Rister 2010).

[d] Although insurance is available for the pump, gearhead, and power unit, it is not acquired for this application (Rister 2010; Lacewell 2010).

[e] Property taxes for the new irrigation wells are assessed to the landowner (Rister 2010; Lacewell 2010).

[f] Annualized payment accounting for asset loss of value over its useful life and opportunity cost of investment capital plus insurance, property taxes, and fixed repairs (Rister et al. 2009), using a capital discount rate of 5.75 percent (Rister 2010; Lacewell 2010).

Table D11. Field Operations for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Field Operations	Assumed Time Periods Field Operations May Occur
Disc	Jul B - Nov B
Disc	Aug A - Dec A
Land Plane	Aug B - Dec B
Bed	Sept A - Dec B
Hip Beds	Oct A - Jan B
Fertilize	Dec A - Feb B
Hip Beds	Dec B - Mar B
Spray	Jan A - Apr A
Condition Beds	Feb A - May B
Plant	Feb B -May B
Cultivate	Mar B - Jun B
Harvest	Jul A - Nov B

Source: Falconer (2009); Popp (2010); Raun (2010); Rooney (2010); and Blumenthal (2010).

Table D12. Field Operations for Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Category	Field Operations	Custom Rate per Acre[a]
Establishment Field Operations	Disc	$12.00
	Disc	12.00
	Spray Herbicide	4.00
	Field Cultivate	10.00
	Grain Drill	10.00
	Fertilize	5.50
Production Field Operations	Fertilize	5.50
	Spray Herbicide	n/a[b]
	Cut	n/a[b]
	Rake	n/a[b]
	Round Bale	n/a[b]
	Haul and Stack	n/a[b]

Source: Blade Energy Crops (2009); Texas AgriLife Extension Service (2009a and b).

[a] This cost does not include the cost of inputs, i.e., fertilizer and herbicide material costs.

[b] These field operations are performed by the Corporate Biomass Feedstock Farming Entity and not custom operators.

Table D13. Available Time Periods for Field Operations for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

		Time Period										
Operation	Description	Jun A	Jun B	Jul A	Jul B	Aug A	Aug B	Sept A	Sept B	Oct A	Oct B	Nov A
1	Disc				X[c]	X	X	X	X	X	X	X
2	Disc					X	X	X	X	X	X	X
3	Land Plane						X	X	X	X	X	X
4	Bed							X	X	X	X	X
5	Hip Beds									X	X	X
6	Fertilize											
7	Hip Beds											
8	Spray											
9	--------[c]											
10	Condition Beds											
Always Planting[a]	Plant											
12	Cultivate	X	X									
13	--------	pt[b]	pt									
14	--------	pt	pt	pt								
15	--------	pt	pt	pt	pt							
16	--------	pt	pt	pt	pt							
17	--------			pt	pt							
Always Harvesting[a]	Harvest			X	X	X	X	X	X	X	X	X
19	--------			pt	pt	pt	pt	pt	pt	pt	pt	pt
20	--------			pt	pt	pt	pt	pt	pt	pt	pt	pt
21	Close Loop, From Last Operation Back to First Operation[d]			X	X	X	X	X	X	X	X	X

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[a] The plant and harvest operations always occur in this order and in the specified slots to allow them to be linked together for use with the yield curve.

[b] "pt" is an abbreviation for pass through and is interpreted to mean a period in which no field operation occurs and land passes through to the next field operation at no cost. Pass through periods are a result of Sorghasaurus'© flexible design allowing up to 20 field operations to be specified. If 20 field operations are not required, the user is allowed to omit any field operation section by allowing the land to pass through.

[c] This operation is not used in the Middle Gulf Coast, Edna-Ganado, Texas area HES application of Sorghasaurus©.

[d] The Close Loop feature represents a realistic production cycle, constraining land that is moving out of the last field operation in year one and only being available for the first field operation in year two during the same or later time periods. This "Loop" effectively simulates a steady state of field operations across time, e.g., prohibiting land with a growing crop from being prepared for planting of the next crop until the growing crop is harvested.

Table D13. (Continued).

Operation	Description	Time Period												
		Nov B	Dec A	Dec B	Jan A	Jan B	Feb A	Feb B	Mar A	Mar B	Apr A	Apr B	May A	May B
1	Disc	X												
2	Disc	X	X											
3	Land Plane	X	X	X										
4	Bed	X	X	X										
5	Hip Beds	X	X	X	X	X								
6	Fertilize		X	X	X	X	X	X						
7	Hip Beds			X	X	X	X	X	X	X				
8	Spray				X	X	X	X	X	X	X			
9	--------[c]					pt	pt	pt	pt	pt	pt	pt		
10	Condition Beds						X	X	X	X	X	X	X	X
Always Planting[a]	Plant							X	X	X	X	X	X	X
12	Cultivate									X	X	X	X	X
13	--------									pt	pt	pt	pt	pt
14	--------									pt	pt	pt	pt	pt
15	--------									pt	pt	pt	pt	pt
16	--------													
17	--------													
Always Harvesting[a]	Harvest	X												
19	--------	pt [b]												
20	--------	pt												
21	Close Loop, From Last Operation Back to First Operation[d]	X												

Source: Falconer (2009); Popp (2010); Rooney (2010); Raun (2010); and Blumenthal (2010).

[a] The plant and harvest operations always occur in this order and in the specified slots to allow them to be linked together for use with the yield curve.

[b] "pt" is an abbreviation for pass through and is interpreted to mean a period in which no field operation occurs and land passes through to the next field operation at no cost. Pass through periods are a result of Sorghasaurus© flexible design allowing up to 20 field operations to be specified. If 20 field operations are not required, the user is allowed to omit any field operation section by allowing the land to pass through

[c] "X" signifies that the designated field operation is performed during the time period.

[d] The Close Loop feature represents a realistic production cycle, constraining land that is moving out of the last field operation in year one and only being available for the first field operation in year two during the same or later time periods. This "Loop" effectively simulates a steady state of field operations across time, e.g., prohibiting land with a growing crop from being prepared for planting of the next crop until the growing crop is harvested.

Table D14. Plant/Harvest Period Combinations for High-Energy Sorghum with Percent of Maximum Yield Expected by Harvest Period, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

		Harvest Period																							
Max yield in dry tons[a]	Plant Period	Jun A	Jun B	Jul A	Jul B	Aug A	Aug B	Sept A	Sept B	Oct A	Oct B	Nov A	Nov B	Dec A	Dec B	Jan A	Jan B	Feb A	Feb B	Mar A	Mar B	Apr A	Apr B	May A	May B
9.0	Feb B[b]			50%	75%	100%	100%	90%																	
	Wet Moisture Content[c]			75%	75%	75%	75%	65%																	
9.5	Mar A				50%	75%	100%	100%	90%																
	Wet Moisture Content				75%	75%	75%	75%	65%																
11.0	Mar B			40%	50%	70%	90%	95%	100%	95%	90%														
	Wet Moisture Content			75%	75%	75%	75%	75%	75%	70%	65%														
12.0	Apr A			40%	50%	70%	90%	95%	100%	95%	90%														
	Wet Moisture Content			75%	75%	75%	75%	75%	75%	70%	65%														
12.0	Apr B				45%	70%	90%	95%	100%	100%	100%	90%													
	Wet Moisture Content				75%	75%	75%	75%	75%	75%	75%	65%													
10.8	May A				30%	45%	70%	85%	90%	100%	95%	85%													
	Wet Moisture Content				75%	75%	75%	75%	75%	75%	70%	65%													
10.2	May B					35%	45%	70%	90%	100%	90%	80%	70%												
	Wet Moisture Content					75%	75%	75%	75%	75%	70%	65%	60%												

Source: Blumenthal (2010); Rooney (2010).

[a] Maximum dry yield for each planting/harvesting period combination are derived as a function of day length and ambient air temperature.

[b] The percentages expressed in these rows represent the percentage of maximum dry yield for each harvest period associated with the respective planting period.

[c] The percentage expressed in these rows represent the wet moisture content of the harvested crop associated with the respective planting period.

Table D15. Yield Curve for Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Abbreviations for Time Periods in This Application of Model	Dry Ton Switchgrass Yield Accounting for Loss due to Overwintering[a]
Jun A	3.00
Jun B	3.00
Jul A	3.00
Jul B	3.00
Aug A	3.00
Aug B	3.00
Sept A	3.00
Sept B	3.00
Oct A	3.00
Oct B	3.00
Nov A	3.00
Nov B	2.85
Dec A	2.70
Dec B	2.70
Jan A	2.55
Jan B	2.55
Feb A	2.40
Feb B	2.40
Mar A	2.25
Mar B	2.40
Apr A	2.40
Apr B	2.55
May A	2.70
May B	2.85

Source: Blade Energy Crops (2009) and own modifications.

[a] Yields between Nov B and Mar A are adjusted to represent a 25 percent dry matter loss due to overwintering. It is assumed that yields decline to a low point during the Mar A period and then yields increase to represent spring regrowth.

Table D16. Variable Input Requirements for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Description of Units	Price per Unit	Number of Units per Acre	Cost per Acre
Fertilizer				
N	lbs	$0.35	240	$84.00
P	lbs	0.45	80	36.00
K	lbs	0.42	160	67.20
Herbicide				
Bicep[a]	pt	5.63	2	11.25
Seed				
ES 5200[c]	lbs	5.00	7	35.00

Source: Falconer (2009); Schulze (2010); Rooney (2010); Blade Energy Crops (2010a); McFarland (2010).

[a] A herbicide that is used to control invasive weeds and grasses to help in HES establishment (Rooney 2010; Blumenthal 2010).

[b] Mention of a trade name does not constitute a recommendation by Texas AgriLife Research or Texas AgriLife Extension Service or Texas A&M University.

[c] ES 5200 is a HES seed produced by Blade© Energy Crops that has a high yielding potential in a single cut harvest and is photo-period sensitive (Blade Energy Crops 2010a).

Table D17. Variable Input Requirements for Switchgrass, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Category	Item	Units	Price per Unit	Number of Units per Acre	Cost per Acre
Establishment Variable Input Requirements	Fertilizer				
	N	-	-	-	-
	P	lbs	$ 0.45	20	$ 9.00
	K	lbs	0.42	40	16.80
	Herbicide				
	Roundup[a,b]	pt	4.75	4	19.00
	Seed				
	EG 1101[c]	lbs	5.00	7	35.00
Production Variable Input Requirements	Fertilizer				
	N	lbs	$ 0.35	60	$ 21.00
	P	lbs	0.45	20	9.00
	K	lbs	0.42	40	16.80
	Herbicide				
	2, 4-D Amine[a,b]	pt	1.88	2.5	4.70
	”square” bale twine	roll	32.00	n/a	n/a

Source: Falconer (2009); Schulze (2010); Rooney (2010); Blade Energy Crops (2010b); Blade Energy Crops (2009); McFarland (2010); Texas Agrilife Extension Service (2009a, 2009b).

[a] Mention of a trade name does not constitute a recommendation by Texas AgriLife Research or Texas AgriLife Extension Service or Texas A&M University.

[b] A herbicide that is used to control invasive weeds and grasses to help in SG establishment.

[c] EG 1101 is an improved Alamo-type SG seed produced by Blade© Energy Crops that is well adapted for use in the southern U.S. (Blade Energy Crops 2010b).

Table D18. Density of High-Energy Sorghum Based On Harvested Moisture Content, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Moisture Content of High-Energy Sorghum When Harvested (%)	Wet Weight of High-Energy Sorghum per Cu-Ft (lbs per cu-ft)[a]	Semi Trailer Loaded Capacity at Specified Density (tons/load)	Semi Trailer Loaded Capacity Dry Ton Equivalent (tons/load)
45	13.0	14.84	9.60
50	15.6	17.81	10.48
55	18.2	20.77	11.00
60	20.8	21.99	10.35
65	23.4	21.99	9.05
70	26.0	21.99	7.76
75	28.6	21.99	6.47

Source: Turhollow et al. (1996)

[a] Two densities were obtained for Turhollow et al. (1996): 15.6 lbs per cu-ft at 50 percent moisture content and 26 lbs per cu-ft at 70 percent moisture content. From these two points, the density was assumed to increase and decrease linearly by 2.6 pounds for each five percent change in moisture content. The equation used is follows: [(26 - 15.6)/4] = 2.6, where four represents the number of intervals between the two observed densities and moisture contents above.

Table D19. Trucking Cost for High-Energy Sorghum, Switchgrass, and Alternative Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Units	Tractor	HES and Alternative Feedstock Trailer	SG Trailer
Purchase Price	$	106,000	51,900	35,000
Expected Useful Life (years)	years	20	22	22
Salvage Value	$	4,109	1,146	773
Annual Fixed Maintenance Cost Rate per $100 of Initial Cost	$	1.00	1.00	1.00
Annual Fixed Insurance Cost	$	5,500	1,000	1,000
Annual License Plate Registration Costs	$	935	25	25
Annual State Inspection Costs	$	62	62	62
Probability of a Major Maintenance Cost [a]	%	15	5	5
Dollar Cost of Major Maintenance Repair	$	650	100	100
Miles per Gallon Fuel Efficiency	mpg	6	n/a[d]	n/a
Miles Driven per Oil Change	miles	20,000	n/a	n/a
Cost of an Oil Change	$	280	n/a	n/a
Miles Driven per Set of Steer Tires	miles	80,000	n/a	n/a
Miles Driven per Set of Drive and Trailer Tires	miles	100,000	100,000	100,000
Cost per Set of Steer Tires	$	600		
Cost of a Set of Drive and Trailer Tires	$	2,400	2,400	2,400
Per Mile Routine Annual Operating Maintenance Costs	$	0.12	0.06	0.06
Other Miscellaneous Per Mile Operating Costs [b]	$	0.03	0.01	0.01
Per Mile Operating Costs	$	0.70	0.09	0.09
Hourly Operating Costs	$	12.37	n/a	n/a
Annuity Equivalent Costs of Ownership [c]	$	17,147	5,896	4,363

Source: Barnes and Langworthy (2003); Bryan Freightliner (2009); Nordstrom (2010); U.S. Environmental Protection Agency (2009); Petro Shopping Centers (2009); Wharton County Tax Assessor Office (2010); Neystel (2010); TxDOT (2010).

[a] Major maintenance cost included replacing the engine, transmission, or repairs due to an accident (Rister 2010).

[b] These costs may include tickets and/or damages done to private property while traveling to the storage or the conversion facility (e.g., running over mailboxes).

[c] Annualized payment accounting for asset loss of value over its useful life, plus insurance, property taxes, and opportunity cost of investment (Rister et al. 2009), using a capital discount rate of 5.75 percent (Rister 2010; Lacewell 2010).

[d] n/a: not applicable.

Table D20. Storage Bunkers for High-Energy Sorghum, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Capacity (cu-ft) [a]	Land Requirements for Storage Bunker (Sq-ft) [b]	Silage Covering Requirement (Sq-ft)	Silage Covering Cost ($/sq-ft)	Purchase Price ($)[c]	Expected Useful Life (years)	Salvage Value ($)	Annual Fixed Maintenance Cost Rate per $100 of Initial Cost ($)	Annual Fixed Insurance Cost Rate per $100 of Initial Cost ($)	Annual Fixed Property Tax Rate per $100 of Initial Cost ($)	Annuity Equivalent Cost of Ownership ($)[c]
Silo Bunker	245,760[d]	40,960	n/a[e]	n/a	$106,600	40	$0.00	$0.00	$0.00	$2.75	$9,794
Silo Covering	n/a	n/a	23,760	0.25	n/a	5	0.00	0.00	0.00	2.75	0.07

Source: Hanson Silo (2009)

[a] Determined by using the following dimensions: 320 feet long, 64 feet wide, and 12 feet high.

[b] Assumed to be double the square footage needed for the silo bunker.

[c] Annualized payment accounting for asset loss of value over its useful life, insurance, property taxes, fixed repairs, and opportunity cost of investment (Rister et al. 2009), using a capital discount rate of 5.750 percent (Rister 2010; Lacewell 2010).

[d] Assuming an average density of 28.60 pounds per cubic foot for HES during the July A period, one bunker can hold 3,514 tons of feedstock, equivalent to about three days of the conversion facility's feedstock requirements during the July A period.

[e] n/a: not applicable.

Table D21. Cellulosic Conversion Facility Biomass Feedstock Requirements for High-Energy Sorghum, Switchgrass, and Alternative Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Time Periods	Number of Days in Corresponding Period	Dry Ton Equivalent Biomass Requirements for Conversion Facility per Operating Hour	Total Dry Ton Equivalent Biomass Requirements for Conversion Facility for all Operating Hours in Corresponding Period[a]
Jun A	15	45.6	16,427
Jun B	15	45.6	16,427
Jul A	15	45.6	16,427
Jul B	16	45.6	17,522
Aug A	15	45.6	16,427
Aug B	16	45.6	17,522
Sept A	15	45.6	16,427
Sept B	15	45.6	16,427
Oct A	15	45.6	16,427
Oct B	16	45.6	17,522
Nov A	15	45.6	16,427
Nov B	15	45.6	16,427
Dec A	15	45.6	16,427
Dec B	16	45.6	17,522
Jan A	15	45.6	16,427
Jan B	16	45.6	17,522
Feb A	14	45.6	15,332
Feb B	14.25[b]	45.6	15,606
Mar A	15	45.6	16,427
Mar B	16	45.6	17,522
Apr A	15	45.6	16,427
Apr B	15	45.6	16,427
May A	15	45.6	16,427
May B	16	45.6	17,522

[a] Assuming a 30-million gallon cellulosic conversion facility and a conversion rate of 75 gallons per dry ton (Avant 2009) at 15 percent moisture content, a total of 400,000 dry tons is required by the conversion facility for one year's operation.
[b] The 0.25 of a day represents averaging out "leap year" over four years.

Table D22. Overhead Management and Support Staff Cost and Labor Structure to Supply a 30-Million Gallon Cellulosic Conversion Faciliy with High-Energy Sorghum, Switchgrass, and Alternative Feedstocks, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

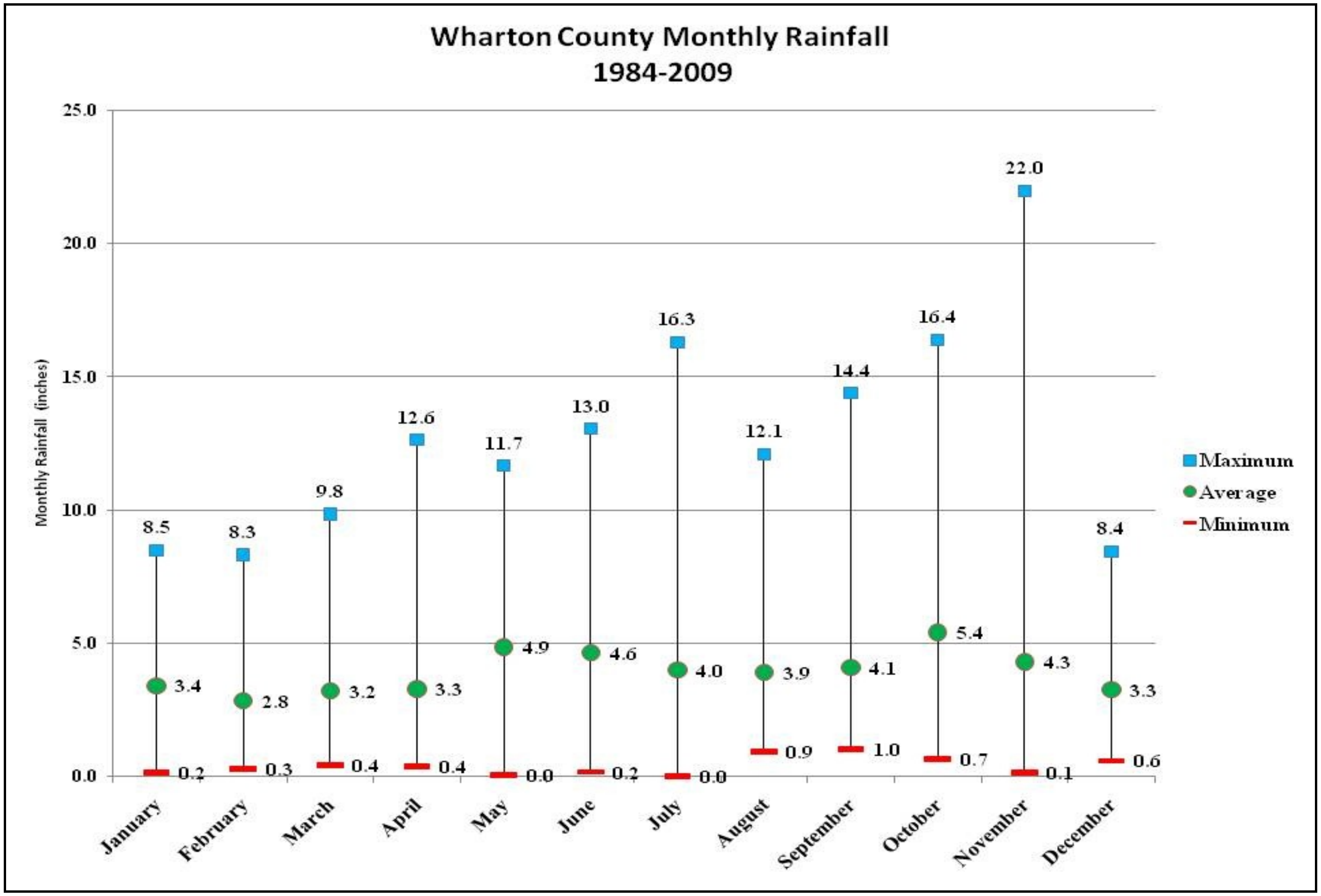
Position	Number of Individuals in this Position	Annual Base Salary per Individual	Health Insurance and Other Benefits Annual Costs[b]	Company's FICA and Other Taxes (% of Base Salary)[c]	Sub-Total per Individual	Total for Position
CEO	1	$300,000	$51,000	$10,987	$361,987	$361,987
VP of Operations	1	150,000	28,500	8,797	187,297	187,297
VP of Finance	1	150,000	28,500	8,797	187,297	187,297
Board of Directors	7	6,000	0	0	6,000	42,000
Logistics Coordinator	2	100,000	21,000	7,650	128,650	257,300
Operations Coordinator	2	100,000	21,000	7,650	128,650	257,300
Field Staff	1 : 5[a]	65,000	15,750	4,973	85,723	n/a
Logistics Supervisor	1 : 5[a]	65,000	15,750	4,973	85,723	n/a
Accounting	2	100,000	21,000	7,650	128,650	257,300
Lawyer	1	125,000	24,750	9,563	159,313	159,313
Computer Technician	2	85,000	18,750	6,503	110,253	220,505
Security Personnel	10	35,000	11,250	2,678	48,928	489,275
TOTAL	29					$1,558,219

Source: Raun (2010); Popp (2010).

[a] One field staff employee is hired for every five machinery/equipment operators and one logistics supervisor is hired for every five transport drivers.

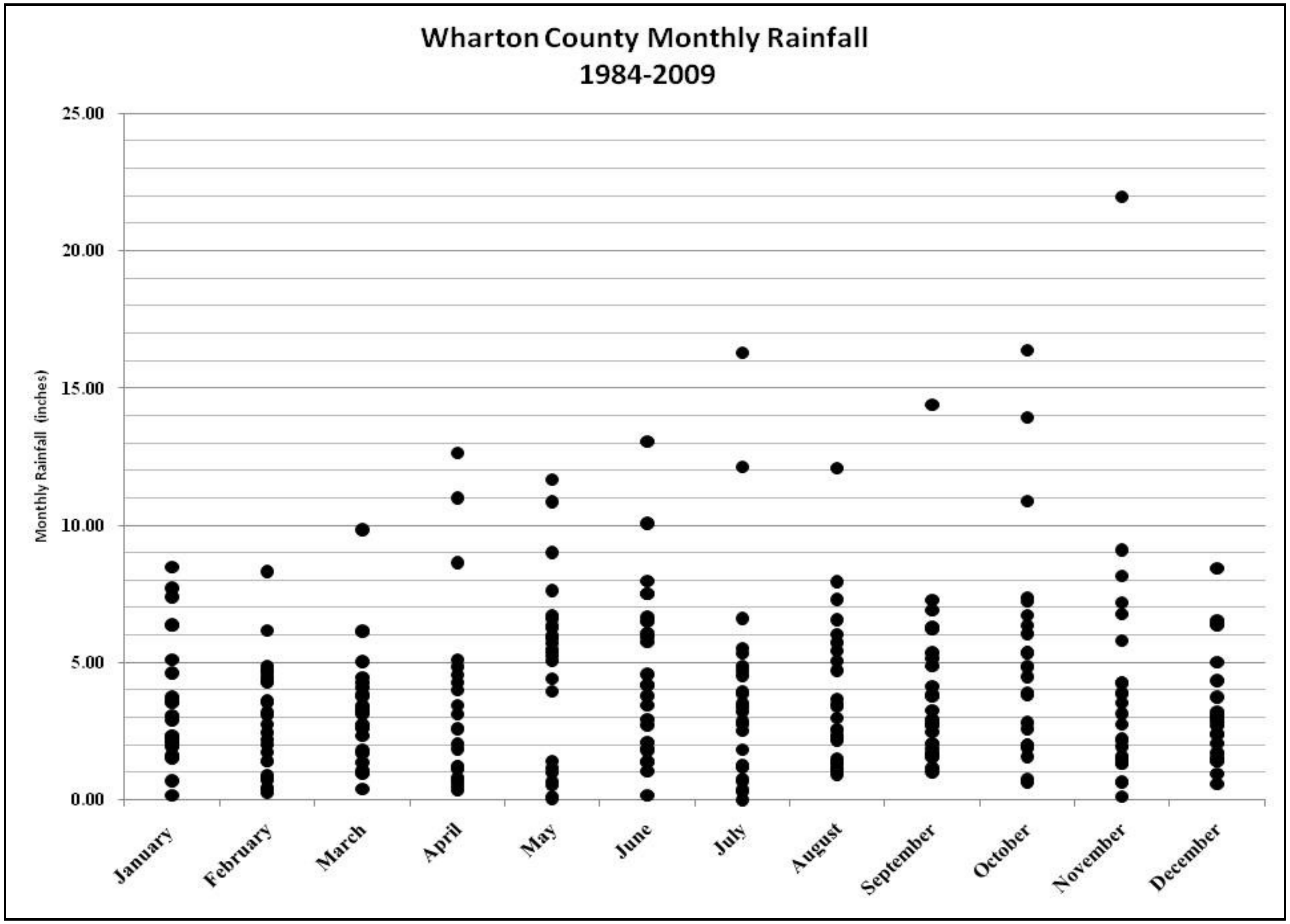
[b] Health insurance is assumed to be $500 per month and other benefits are calculated as 15 percent of annual base salary (Rister 2010; Lacewell 2010).

[c] FICA and Medicare: Medicare is calculated as 1.455 percent of the base salary with no maximum limit, and Social Security is calculated as 6.2 percent of the base salary up to a maximum salary of $106,800 (Brooks 2009).



Source: Original data from Raun (2010) and own modifications.

Figure D1. Average and Range of Wharton County Monthly Rainfall for Years 1984 - 2009.



Source: Original Data from Raun (2010); Leidner (2010); and own modifications.

Figure D2. Individual Occurrence of Wharton County Monthly Rainfall for Years 1984 - 2009.

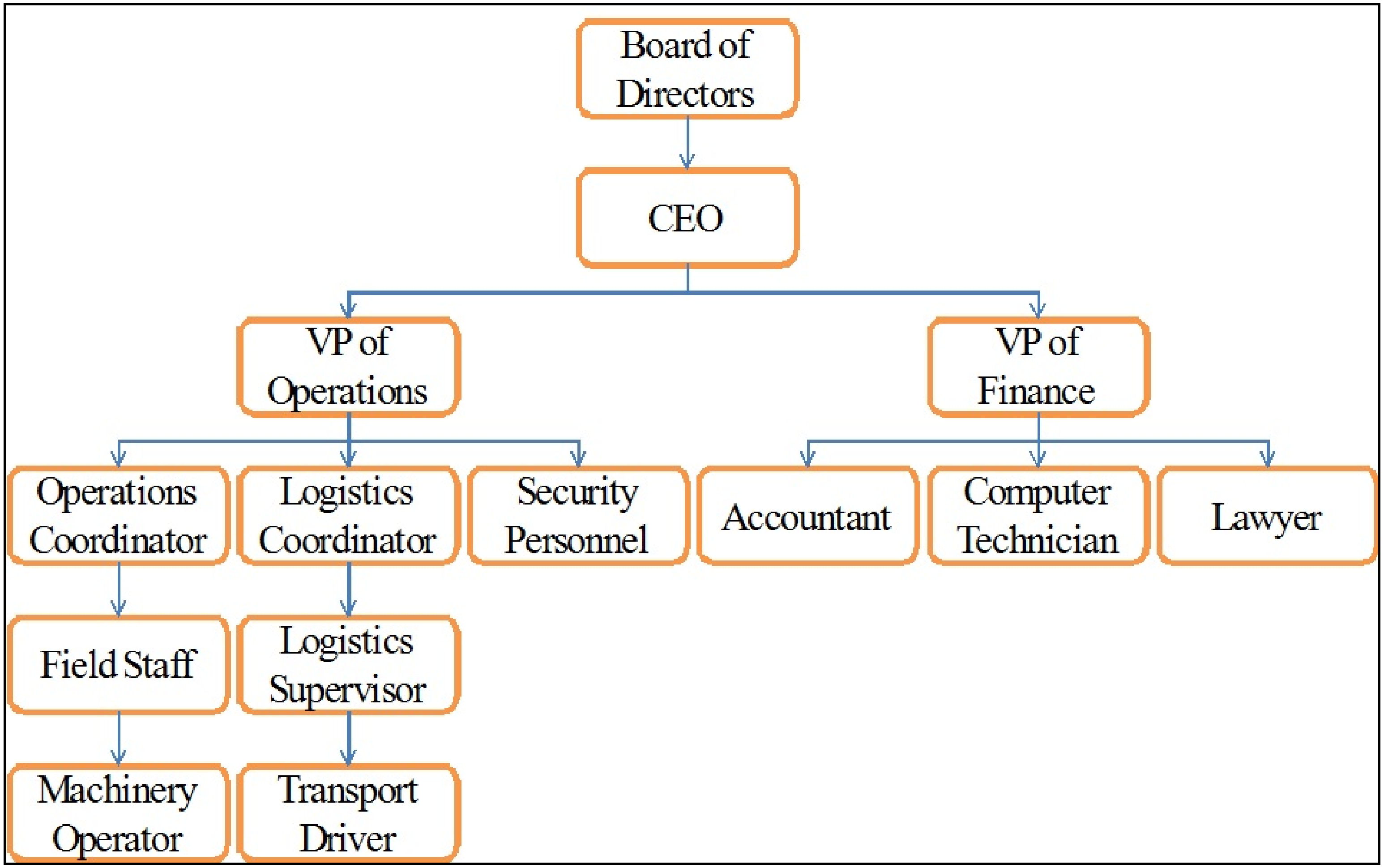


Exhibit D1. Overhead Management and Support Staff Labor Structure, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

APPENDIX E

SENSITIVITY SCENARIOS

SENSITIVITY SCENARIOS

Results for the 40 sensitivity scenario analyses conducted as part of this thesis research are presented in expanded detail within this Appendix. Table E1 is intended to provide a roadmap to each of the sensitivity scenarios, and includes an itemized listing of the individual scenarios and an indication of the respective page numbers for the discussion text and tables corresponding to each. Four tables of Sorghasauras© results are presented for each scenario:

- a summary comparison of select critical solution values for the scenario relative to the same standards identified for the Year 2 Baseline Scenario;
- a report of the number and associated total initial investment and amortized costs of the requisite capital machinery, equipment, land, buildings, and SG custom establishment for the scenario;
- a report regarding details of the annual operating costs for the scenario; and
- a summary table for the scenario, identifying
    - total annual cost for the hypothetical corporate biomass feedstock farming entity;
    - cost per planted acre of biomass feedstock;
    - cost per dry ton of biomass feedstock;
    - cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and

* proportion of total annual costs distributed between capital investment and annual operating costs.

These cost details are presented here to provide documentation supporting the corresponding discussion presented in the primary text section. Text discussion for each scenario is first presented, with reference to the four respective support tables. Emphasis in such text is focused on recognizing:

- the associated changes in Year 2 Baseline Scenario parameters which form the basic elements of the sensitivity scenario;
- the resulting critical solution values for the scenario;
- explanations and discussion of the apparent/supposed cause-effect relationships responsible for the magnitude and direction of the results relative to the Year 2 Baseline Scenario results, providing insights into the importance of the various factors changed in the scenario; and
- a capsulated summary of 'take aways' from the scenario analysis.

While many of the results discussed in this Appendix are directly reported in the accompanying tables, there are numerous instances of the discussion including results beyond those reported in such tables. The intent of such discussion is to provide an extensive explanation of the phenomena underlying the results without overly burdening the reader with an excess of report tables.

Sensitivity Scenario 1A: Three Extra Periods of Biomass Conversion Facility Biomass Feedstock Requirements

The cost implications associated with producing an extra three periods' supply of biomass feedstock (49,281 dry tons)[138] are investigated in this scenario. This biomass feedstock is used as insurance against crop failure and unexpected interruptions in timeliness of within-year biomass feedstock arrivals at the conversion facility and is not used by the conversion facility during the operating year. However, it is assumed that all biomass feedstocks are used by the conversion facility on a first-in-first-out (FIFO) basis, with no surplus biomass feedstocks remaining in storage indefinitely.

This required increase in production impacts the required capital investments and annual operating costs due to the increased size of the farming operation. Although this is a one-time phenomenon (i.e., producing the equivalence of three periods of the conversion facility's biomass feedstock requirements and placing it in storage), the approach taken in this sensitivity scenario is to compare the costs of sustained production at this level relative to sustained production without the extra three periods (i.e., Year 2 of the Baseline Scenario).

Tables E2, E3, E4, and E5 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario. The total annual costs under this scenario are estimated to be $62.19 million; i.e., an increase from the Year 2 Baseline Scenario of $8.59 million (table E2). The required

[138] The user is allowed to specify the amount of additional biomass feedstock to produce for inventory insurance. This biomass feedstock is used to provide a cushion (i.e., insurance) against the possibility of crop failure, harvest/ transport problems, etc. and the CBFFE not being able to meet the biomass conversion facility's biomass feedstock requirements on a timely basis.

number of HES acres increases by 7,105 acres (19.28 percent) while the required number of SG acres increases by 371 acres (1.00 percent) due to the increase in required production. A total of 373,159 dry tons of HES is produced on 43,950 acres while a total of 100,000 dry tons of SG is produced on 37,596 acres to meet the annual needs of the conversion facility; thus, totaling 473,159 dry tons of biomass feedstock harvested on 81,546 acres. Dividing total annual costs by total acres results in a per acre cost of $762.60. Costs per dry ton of biomass feedstock production are $138.42 and the biomass feedstock-logistics-only cost per gallon of biofuel is $2.0729.[139]

Total capital investment costs are estimated to be $136.09 million while the costs on an annual basis are estimated to be $17.24 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) for this scenario (table E3). This translates into an increase of initial investment costs of $17.84 million and a cost increase on an annual basis of $2.31 million (table E2). Increasing the required biomass feedstock production significantly impacts the required number of semi truck-trailer units, harvesters, irrigation wells, and storage units (table E3). The required number of harvesters is increased by 3 units, totaling a cost increase of $273 thousand. The required number of semi truck-trailer units is increased by 21 units, resulting in an annual cost increase of $484 thousand. The required number of irrigation wells and storage units are increased by 9 and 54 units, respectively. The increase in required irrigation wells increases annual costs by $191 thousand while the increase in the number of storage units increases annual costs by $529 thousand. Combined, the

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[139] Cost per gallon of fuel was determined by dividing total annual cost by 30 million gallons, since a 30-million gallon/year conversion facility is assumed.

increase in the required number of these four capital items results in an annual cost increase of $1.48 million.

Total annual operating costs are estimated to be $44.94 million (table E4); an increase from the Year 2 Baseline Scenario cost of $6.26 million on an annual basis (table E2). Increasing required biomass feedstock production significantly impacts the costs associated with leasing land, hiring labor, irrigation, and fertilizing (table E4). The required number of HES acres increases by 7,105 acres while the number of full-time laborers increases by 40 people. The increase in required HES land increases total annual operating costs by $409 thousand while the increase in the required number of full-time employees increases annual operating costs by $1.96 million.

The increased required biomass feedstock and the subsequent increase in HES acreage increases irrigation costs by $663 thousand. The increase in HES acreage due to increased biomass feedstock production increases the costs of fertilizing by $1.35 million. A total of 10.55 million pounds of nitrogen, 3.52 million pounds of phosphorus, and 7.03 million pounds of potassium are required, totaling $8.23 million[140]. This results in an increase of 3.41 million pounds of fertilizer nutrients, totaling $1.33 million.

Table E5 is a summary for Scenario 1A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital

[140] For a maximum-expected HES yield of 12 dry tons per acre, 240 pounds of nitrogen, 80 pounds of phosphorus, and 160 pounds of potassium are required to be applied per acre.

investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are:

- Establishment of additional HES storage inventory to protect (insure) against delays in deliveries to the conversion facility is costly, exceeding $20.00 per dry ton of biomass feedstock required (but only on a one-time basis); and
- The opportunity to purchase additional biomass feedstock from an outside source may prove a more cost-effective approach to insure against delays in deliveries of CBFFE-produced biomass feedstocks to the conversion facility.

Sensitivity Scenario 1B: Additional SG Production Equivalent to 25 percent of Conversion Facility's Annual Biomass feedstock Requirements

In this scenario, the only variable changed from the Year 2 Baseline Scenario is that no excess SG acreage is established for insurance. The intent here is to identify what costs are associated with maintaining the yield insurance in the form of 40,000 acres of growing SG available for harvest in the event of sub-par harvested HES and/or SG yields. Tables E6, E7, E8, and E9 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $52.0 million, i.e., $1.7336 per gallon of fuel produced, $702.13 per harvested acre of HES and SG, and $130.02 per dry ton of the requisite 400,000 tons of biomass feedstock (table E6). Eliminating the 40,000 acres of insurance SG acreage reduces the total annual supply costs by $1.6 million, i.e., by $0.0531 per gallon of fuel produced, by $21.54 per harvested acre of HES and SG biomass feedstock, and by $3.99 per dry ton (table E6). Percentage-wise, it appears that the SG insurance acreage comprises 2.98 percent of the costs identified in the Year 2 Baseline Scenario.

Reducing SG insurance land to zero has no effect on the amount of HES and SG land used for production, the amount of HES and SG tons produced, or the average yields for each biomass feedstock. The total requisite initial investment for the CBFFE is estimated to be $106.32 million while the cost on an annual basis is estimated to be $14.04 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E7), resulting in an annual cost decrease of $898 thousand (table E6). Since SG insurance land is established using custom operators and is not harvested unless needed, there is no reduction in the amount of machinery and equipment purchased.

The only reduction in capital investment costs is with respect to eliminating the costs to have the SG insurance land custom established. The annual costs of this operation are reduced by $878 thousand. Total annual operating costs are estimated to be $37.96 million (table E8), representing a $718 thousand decrease on an annual basis from the baseline scenario (table E6). This reduction is attributable to the elimination of fertilizer and other annual production expenses (e.g., herbicides) on the SG insurance acreage. The amount of SG land used for insurance is reduced by 40,000 acres and constitutes an annual costs reduction of $700 thousand. The reduction in operating costs also reduces the costs of borrowing operating money by $18 thousand. Thus, the only reduction in costs by eliminating SG insurance acreage is on the costs of custom establishment, leasing SG insurance land, and borrowing operating money.

Table E9 is a summary for Scenario 1B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above is upkeep of additional biofuel SG biomass feedstock production acreage to protect (insure) against realization of lower-than-expected harvested biomass feedstock yields is costly (i.e., \$3.99 per dry ton of biomass feedstock required by the conversion facility – 2.98 percent of total costs), although not as costly as producing three extra periods of HES (i.e., as discussed for Scenario 1A).

Sensitivity Scenario 2A: HES Yield @ 8 Dry Tons per Acre

In this scenario, decreasing the maximum-expected HES harvested yield from 12 to eight dry tons per acre and removing irrigation requirements are the two principal variables changed from the Year 2 Baseline Scenario. The pounds of fertilizer nutrients applied per acre are also decreased to recognize the expectations of decreased biomass tonnage removed per acre. Tables E10, E11, E12, and E13 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

In interpreting the logic and rationale responsible for and the implications of these results, readers are reminded that the Sorghasaurus© modeling approach seeks to minimize overall costs of supplying biomass feedstocks to a cellulosic conversion facility year-round while accounting for capital and operating costs. Tradeoffs among such costs as affected by distribution of activities across the allowed bi-weekly time periods are explicitly recognized within the model.

The total annual cost to supply a 30-million gallon conversion facility with biomass feedstock for one-year is estimated to be $53.15 million for this scenario (table E10). This magnitude of cost translates into $1.7715 per gallon of fuel, $565.02 per acre of biomass feedstock harvested, and $132.87 per dry ton of the requisite 400,000 dry tons of biomass feedstock required by the conversion facility. Somewhat unexpectedly, reducing expected HES yield levels and removing the irrigation requirements translates into annual costs savings of $456 thousand and lower per unit costs, i.e., reductions of

$0.0152 per gallon of fuel, $158.65 per acre of harvested biomass feedstock, and $1.14 per dry ton (table E10).

Reflections on these results are suggestive that the requisite increase in HES acreage to meet the annual biomass feedstock requirements when (1) average-expected harvested HES yields are reduced by 4 tons per acre (i.e., 12-8) (translating into a realized reduction of 2.91 tons, i.e., 8.50 to 5.59 dry tons per acre) and (2) irrigation requirements are eliminated allows for a substantial reduction in average (per acre and per harvested dry ton) capital investments. In effect, this is a case of substituting extensive-farming for intensive-farming operations. It is important to note that the assumptions of this scenario include that adequate additional acreage is assumed available and that the land rental market is unaffected by the increased demand for acreage, i.e., planted HES acreage increases by 19,577 (53.13 percent) and total HES and SG acreage (including rotation acreage) increases by 59,145 (table E10).

Dividing the total annual cost by the total acres and the total tons of biomass feedstock produced results in an annual per acre cost of $565.02 and a per dry ton delivered and stored biomass feedstock cost of $132.87, respectively. Assuming a fuel conversion rate of 75 gallons per dry ton (Avant 2009) and a 30-million gallon conversion facility size, total-delivered biomass feedstock costs is $1.7715 per gallon of fuel produced (table E10).[141]

Total capital investment costs are estimated to be $97.93 million while the costs on an annual basis are estimated to be $13.86 million (calculated on an annuity

[141] Cost per gallon of fuel was determined by dividing total annual cost by 30 million gallons, since a 30-million gallon/year conversion facility is assumed.

equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) for this scenario (table E11). These results translate into a reduction of initial investment costs of $20.32 million and a cost reduction on an annual basis of $1.06 million (table E10). Removing the necessity of irrigation eliminates the 78 irrigation wells and the 246 re-lift pumps required in the Year 2 Baseline Scenario, resulting in annual cost reductions of $1.67 million and $405 thousand, respectively. This reduction in costs is partially offset by the increased headquarters, machinery, and storage requirements associated with increased HES acreage due to the decreased maximum-assumed per acre HES yield.

Although the amount of wet tonnage harvested increases, the number of semi trucks and HES end-dump trailers actually decreases to 112 units. The reduction is due to the spreading out of harvesting operations over more periods and harvesting less biomass feedstock during the most restrictive trafficable day periods. For example, during the most-restrictive trafficable-day September B period, only 36 trafficable hours are available for use and under the Year 2 Baseline Scenario, 39,027 wet tons are harvested. For Scenario 2A, 38,009 wet tons are harvested during this period; thus, reducing the number of semi trucks and trailer units required.

Total annual operating costs are estimated to be $39.29 million (table E12); an increase from the baseline results of $608 thousand on an annual basis (table E10). Although decreasing the HES maximum-expected yield would suggest a substantial increase in operating costs as a result of the required increase in acreage, that increase in costs is offset by reducing irrigation capital and operating costs to zero. Under the Year 2 Baseline Scenario, pumping irrigation water accounts for $3.44 million (8.89 percent) of the total operating costs of $38.68 million, i.e., $46.42 per harvested acre, $8.60 per dry ton, and $0.1146 per gallon of fuel. Thus, the total costs associated with omitting irrigation results in a costs savings of $3.44 million on an annual basis and a reduction of 614,199 acre-inches of water pumped and applied.

Decreasing maximum-expected HES yield as portrayed in this sensitivity scenario has an almost nonexistent effect on the costs of fertilizing. As noted earlier, as expected HES maximum yield decreases, the pounds of fertilizer nutrients required per acre also decreases. However, the decreased yields substantially increase the acreage required, partially offsetting the initial savings. A total of 9.03 million pounds of nitrogen, 3.01 million pounds of phosphorus, and 6.02 million pounds of potassium are required, summing to 18.06 million pounds annually[142]. This scenario results in an increase of 369 thousand pounds of fertilizer, totaling $144 thousand.

Table E13 is a summary for Scenario 2A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Realization of harvested biomass feedstock yields different than assumed in the baseline scenario affects costs in a complex, myriad of interrelationships among the

[142] For a maximum-expected HES yield of eight dry tons per acre, 160 pounds of nitrogen, 53.3 pounds of phosphorus, and 80 pounds of potassium are required per acre.

various segments of the holistic production-harvesting-transportation-storage logistics supply-chain system;

- The representation of reality integrated into Sorghasaurus© offsets/compensates for some of the yield change impacts by making adjustment in other activity levels subject to the numerous specified constraints;
- Reducing HES maximum-expected yield to 8 dry tons per acre and removing the irrigation requirements result in a slightly-lower per dry ton biomass feedstock cost (i.e., $1.14) than for the Year 2 Baseline Scenario due to the elimination of substantial irrigation costs; and
- There is a minimal effect on the costs of fertilizing due to the tradeoff between (1) reduced maximum-expected yield and the decreased fertilizer nutrient requirements and (2) the increased acreage.

Sensitivity Scenario 2B: HES Yield to 12 Dry Tons per Acre and No Irrigation

In this scenario, the HES maximum-expected yield of 12 dry tons per acre is maintained, and irrigation requirements are set to zero and the costs savings associated with this change are evaluated. That is, the only variable changed is irrigation water requirements are reduced from 16.67 acres-inches per acre to zero, eliminating both the capital investment and operating costs associated with irrigation. Tables E14, E15, E16, and E17 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

Under this scenario, the total annual supply costs are estimated to be $47.53 million, i.e., $1.5844 per gallon of fuel produced, $625.88 per harvested acre of HES and SG, and $118.83 per dry ton of the requisite 400,000 tons of biomass feedstock (table E14). Removing irrigation requirements reduces the total annual supply costs by $6.07 million (11.33 percent), i.e., by $0.2023 per gallon of fuel produced, $97.79 per harvested acre of HES and SG, and $15.18 per dry ton (table E14). A total of 315,434 dry tons of HES are produced on 38,269 acres while a total of 100,000 dry tons of SG is produced on 37,675 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 415,434 dry tons on 75,944 acres. The amount of HES land required increases from the Year 2 Baseline Scenario by 1,424 acres while the amount of SG land increases by 450 acres; these minor changes in acreage are associated with slight adjustments in timing of production, irrigation, and harvesting operations.

Average HES yields equate to 8.24 dry tons per acre and 2.65 dry tons per acre for SG, a slight decrease of 0.26 dry tons per acre for HES and 0.04 dry tons per acre for SG (table E14). Since a harvest yield curve is utilized to determine the yield per acre during each period, the yield per acre for each respective biomass feedstock depends on the periods of planting and harvest (i.e., the expected percentage of maximum yield available for each specific allowed planting period/harvest period combination). Thus, in the search for an optimal solution under the new parameters, more acreage was harvested during non-peak HES yields, resulting in a lower average-harvested yield per acre.

The total requisite initial investment for the CBFFE is estimated to be $90.68 million while the cost on an annual basis is estimated to be $12.34 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E15), resulting in an annual cost savings of $2.58 million (table E14). Total annual operating costs are estimated to be $35.19 million (table E16), representing a $3.49 million reduction on an annual basis from the Year 2 Baseline Scenario (table E14).

Table E17 is a summary for Scenario 2B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are:

- Providing irrigation to protect against unusually dry years and no/minimal biomass feedstock production is expensive; and
- Removing the required irrigation allows the model to bypass consideration of the requisite joint timing of irrigation and planting, resulting in more acreage being harvested during non-peak times and reduces average dry ton yields.

Sensitivity Scenario 2C: HES Yield to 18 Dry Tons per Acre

In this scenario, increasing the maximum-expected HES harvested yield from 12 to 18 dry tons per acre is the only variable changed from the baseline assumptions; e.g., irrigation continues at the levels assumed in the baseline. Increasing the expected HES biomass feedstock yields impacts (i.e., increases) the nutrient requirements (i.e., pounds of fertilizer nutrients per acre) of the biomass feedstock. Therefore, the pounds of fertilizer nutrients applied per acre are increased proportionate to the expected increase in tonnage of biomass feedstock removed per acre. Tables E18, E19, E20, and E21 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $47.85 million, i.e., $1.5949 per gallon of fuel produced, $755.34 per harvested acre of HES and SG, and $119.62 per dry ton of the requisite 400,000 tons of biomass feedstock (table E18). Increasing expected HES yields to 18 dry tons/acre reduces the total annual supply costs by $5.75 million, i.e., by $0.1918 per gallon of fuel produced and $14.39 per dry ton (table E18). Cost per acre increases due to less acreage being available to spread the total capital costs across. Extrapolating in linear fashion, each additional dry ton of maximum biomass feedstock yield reduces supply costs by $2.40 per ton.[143]

[143] Such "simple" calculation can perhaps be misleading in that the underlying cause-effect relationship between changes in variable levels and resulting cost reductions may not be linear, due to the myriad of factors involved and the interactions among those factors. Thus, when a specific parameter is of intense interest, analyses involving smaller, more discrete increments are appropriate. For example, in this case, a series of scenarios consisting of 13, 14, 15, 16, 17, and 18 dry ton yields per acre would be appropriate.

A total of 315,269 dry tons of HES is produced on 25,787 acres while a total of 100,000 dry tons of SG is produced on 37,559 acres to meet the annual biomass feedstock needs of the conversion facility (table E18). Thus, the total amount of biomass feedstock produced is 415,269 dry tons on 63,346 planted acres (114,920 acres in total, including HES rotation acreage). Although the amount of land required decreases by 11,058 acres, the number of dry tons of HES produced actually increases by 2,003 dry tons. This increase in production is driven by the timing of the HES harvest and the subsequent model-user-defined periodic storage deterioration factor incorporated in Sorghasaurus©. As more biomass feedstock is harvested during the early harvest periods, the amount of biomass feedstock transferred from period to period increases, thus increasing the amount of biomass feedstock deterioration and reducing the overall quantity of the biomass feedstocks in storage. This results in more biomass feedstock needing to be harvested to meet periodic requirements of the conversion facility.

For this sensitivity scenario, average HES and SG harvested yields equate to 12.23 dry tons per acre and 2.66 dry tons per acre, respectively (table E18). As expected, realized HES yield per acre increased, resulting in fewer acres of HES land being required to meet the conversion facility's periodic requirements. Dividing the total annual cost by the total acres and the total tons produced results in an annual per acre cost of $755.34 and a per dry ton delivered and stored biomass feedstock cost of $119.62. Assuming a fuel conversion rate of 75 gallons per dry ton (Avant 2009) and a 30-million gallon conversion facility size, total-delivered biomass feedstock costs is \$1.5949 per gallon of fuel produced (table E18).[144]

The total requisite initial investment for the CBFFE is estimated to be \$103.95 million while the cost on an annual basis is estimated to be \$12.87 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E19), resulting in an annual cost savings of \$2.05 million or \$342 thousand per one dry ton increase in maximum HES yields (table E18). An increase in expected and resulting realized HES maximum yield (and resulting reduced HES acreage) has a significant impact on machinery requirements, requiring a total of 72 less pieces of machinery. The most notable reductions in terms of units required is on irrigation wells and re-lift pumps. A total of 56 irrigation wells are required (table E19) (compared to 78 for the Year 2 Baseline Scenario), totaling a savings of \$469 thousand on an annual basis. The required number of re-lift pumps was reduced to 172, resulting in annual savings of \$122 thousand.

The noted increase in yields also has a significant impact on the required number of semi truck units and harvesters. A total of 107 semi trucks and semi trailers are required (table E19) (compared to 115 for the Year 2 Baseline Scenario) while the number of harvesters required decrease to nine (compared to 13 for the Year 2 Baseline Scenario). Although the amount of wet tonnage harvested increases, the number of semi trucks and HES actually decreases to 107 units. The reduction is due to the spreading out of harvesting operations over more periods and harvesting less biomass feedstock during

[144] Cost per gallon of fuel was determined by dividing total annual cost by 30 million gallons, since a 30-million gallon/year conversion facility is assumed.

the most-restrictive trafficable-day periods. For example, during the September B period, 36 trafficable hours are available for use and under the Year 2 Baseline Scenario, 39,027 wet tons are harvested. For this scenario (i.e., 2C), 36,312 wet tons are harvested during the September B period; thus, reducing the number of semi trucks and trailer units required. Reductions in the required numbers of these two capital items result in annual cost savings of $184 thousand and $365 thousand, respectively.

Total annual operating costs are estimated to be $34.98 million (table E20), representing a $3.70 million reduction on an annual basis from the Year 2 Baseline Scenario or $730 thousand per one dry ton increase in maximum HES yields (table E18). Due to the increase in average HES harvested yields per acre, the acreage required for HES production is reduced by 11,058 acres. This reduction in acreage has a substantial impact on the costs of irrigation, planting, and harvesting due to the reduction in the required amount of variable inputs (i.e., water, HES seed, fuel, etc.). Irrigation water requirements are reduced by 184,329 acre-inches, resulting in a cost savings of $1.03 million. This reduction in water requirements (occurring because of reduced acreage) reduces the overall number of irrigation wells.

As noted in the Year 2 Baseline Scenario, fertilizing constitutes a substantial portion of total annual supply costs. Under this scenario, a total of 9.28 million pounds of nitrogen, 3.09 million pounds of phosphorus, and 6.12 million pound of potassium are required, summing to 18.57 million pounds annually. As more biomass is removed per acre, the nutrient requirements per acre increases. That is, for every expected ton of biomass being removed, 20 pounds of nitrogen, 6.67 pounds of phosphorus, and 13.33

pounds of potassium are required. Thus, the increased yields results in an increase of 881 thousand pounds of fertilizer nutrients and constitutes a cost increase of $344 thousand a year.

Table E21 is a summary for Scenario 2C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Increasing HES maximum-expected yield to 18 dry tons per acre reduces the cost per dry ton of biomass feedstock; and
- Increasing HES maximum-expected yield has a significant impact on capital investment costs as less machinery and equipment items are required due to reduced acreage.

Sensitivity Scenario 2D: HES Yields to 25 Dry Tons per Acre

In this sensitivity scenario, increasing the maximum-expected HES harvested yield from 12 to 25 dry tons per acre is the only variable changed from the Year 2 Baseline Scenario assumptions. Since HES maximum-expected yields are increased, the pounds of fertilizer nutrients applied per acre are also increased to accommodate the expected increased tonnage removed per acre. Tables E22, E23, E24, and E25 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $44.62 million, i.e., $1.4872 per gallon of fuel produced, $794.87 per harvested acre of HES and SG, and $111.54 per dry ton of the requisite 400,000 tons of biomass feedstock (table E22). Increasing HES maximum yields to 25 dry tons/acre reduces the total annual supply costs by $8.99 million or by $0.2995 per gallon of fuel produced and $22.47 per dry ton (table E22). Cost per acre increases by $71.20 due to more fertilizer nutrients being applied per acre and less acreage in total available to spread the capital ownership costs across. Extrapolating in linear fashion, each additional dry ton of maximum biomass feedstock yield reduces supply costs by $1.73 per ton.[145]

[145] Such "simple" calculation can perhaps be misleading in that the underlying cause-effect relationship between changes in variable levels and resulting cost reductions may not be linear, due to the myriad of factors involved and the interactions among those factors. Thus, when a specific parameter is of intense interest, analyses involving smaller, more discrete increments are appropriate. For example, in this case, a series of scenarios consisting of 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25 dry ton yields per acre would be appropriate.

A total of 316,709 dry tons of HES are produced on 18,327 acres while a total of 100,000 dry tons of SG is produced on 37,802 acres to meet the annual biomass feedstock needs of the conversion facility (table E22). Thus, the total amount of biomass feedstock produced is 416,709 dry tons on 56,129 planted acres (92,783 acres in total, including HES rotation acreage). Although the amount of land required decreases by 18,518 acres, the number of dry tons of HES produced actually increases by 3,443 dry tons. This increase in production is driven by the timing of the HES harvest and the subsequent model-user-defined periodic storage deterioration factor incorporated in Sorghasaurus©. As more biomass feedstock is harvested during the early harvest periods, the amount of biomass feedstock that is transferred from period to period increases, thus increasing the amount of biomass feedstock deterioration and reducing the overall quantity of the biomass feedstocks in storage. This results in more biomass feedstock needing to be harvested to meet periodic requirements of the conversion facility over a 12-month operating cycle.

The total requisite initial investment for the CBFFE is estimated to be $96.65 million while the cost on an annual basis is estimated to be $11.74 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E23), resulting in an annual cost savings of $3.18 million or $245 thousand per one dry ton increase in maximum HES yields (table E22). Total annual operating costs are estimated to be $32.88 million (table E24), representing a $5.80 million reduction on an annual basis from the Year 2 Baseline Scenario or $446 thousand per one dry ton increase in maximum HES yields (table E22).

For this sensitivity scenario, average HES and SG harvested yields equate to 17.28 dry tons per acre and 2.65 dry tons per acre, respectively (table E22). The increase in average HES harvested yields has a significant impact on the number of acres required and associated machinery requirements and variable operating costs. As expected, fewer acres of HES land are required to meet the conversion facility's periodic requirements and related capital investment and annual operating costs are reduced.

Table E25 is a summary for Scenario 2D of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Increasing HES maximum yield to 25 dry tons per acre significantly reduces the costs of delivering biomass feedstock to the conversion facility; and
- The reduction in the required HES acreage due to increased average yields results in substantial decreases in the required number of capital investments and annual operating costs.

Sensitivity Scenario 3A: SG Yields to 2 Dry Tons per Acre

In this scenario, decreasing the maximum-expected SG harvested yield from three to two dry tons per acre is the only variable changed from the baseline assumptions. Decreasing the expected SG biomass feedstock harvested yield impacts (i.e., reduces) the nutrient requirements (i.e., pounds of fertilizer nutrients per acre) of the biomass feedstock. Therefore, the pounds of fertilizer nutrients applied per acre are decreased proportionate to the expected decreased tonnage of biomass feedstock removed per acre. In addition, insurance SG acreage is increased from 40,000 to 55,000, in recognition of the lower expected yields. Tables E26, E27, E28, and E29 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $56.26 million, i.e., $1.8754 per gallon of fuel produced, $604.41 per harvested acre of HES and SG, and $140.65 per dry ton of the requisite 400,000 tons of biomass feedstock (table E26). Decreasing SG yields to 2 dry tons per acre increases the total annual supply costs by $2.66 million, i.e., by $0.0887 per gallon of fuel produced and $6.64 per dry ton (table E26). The costs per acre are decreased due to more, less expensive (per acre) SG acreage being farmed and being available to spread the capital ownership costs across.

A total of 314,693 dry tons of HES is produced on 36,864 acres while a total of 100,000 dry tons of SG is produced on 56,222 acres to meet the annual biomass

feedstock needs of the conversion facility (table E26). Thus, the total amount of biomass feedstock produced is 414,693 dry tons on 93,086 acres. For this sensitivity scenario, average HES and SG yields equate to 8.54 dry tons per acre and 1.78 dry tons per acre, respectively. As expected, SG yield per acre decreased, resulting in more acres of SG land being required to meet the conversion facility's periodic requirements. HES average yields increase by 0.04 dry tons per acre in response to the reduction in maximum-expected SG yield, with this result occurring due to slight adjustments in HES planting/harvesting timing. Due to the decrease in maximum-expected SG yields, the amount of SG land established for insurance was increased by 15,000 acres.[146]

A decrease in expected SG maximum-expected yield has a nominal impact on capital investment costs. The total requisite initial investment for the CBFFE is estimated to be $130.49 million while the cost on an annual basis is estimated to be $15.96 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E27), resulting in an annual cost increase of $1.04 million (table E26). The required gross number of machinery units purchased for both HES and SG field operations is reduced by 6 units and totals an annual cost decrease of $101 thousand. SG machinery requirements remain unchanged while HES machinery requirements are reduced by 6 units[147].

[146] In the Year 2 Baseline Scenario, 40,000 acres of SG land is established for insurance purposes. In this scenario, 55,000 acres of SG land is established which is equivalent to approximately 25 percent of the conversion facility's yearly biomass feedstock needs. The increase in acreage was determined by dividing 100,000 dry tons by the average SG yield of 1.84 dry tons per acre across all 24 bi-weekly periods.

[147] The change in SG machinery is a net number. The numbers of tractors size 2 (152 hp), hay cutters, and "square" balers increase by 2 tractors, 2 hay cutters, and 1 "square" baler, respectively. The numbers of SG semi trailers and hay squeezes decrease by 3 semi trailers and 2 hay squeezes, respectively.

Although HES acreage only increases by 19 acres, the number of irrigation wells required increases by 8 wells (table E27), totaling an increase of $171 thousand on an annual basis. The change in HES acreage would suggest a fractional increase in irrigation well requirements; however, to realize increased average HES yields, more acreage is planted during the periods of higher-expected maximum HES yields, thus increasing the number of irrigation wells required. Although the change in the required number of machinery units required is not substantial, the decrease in SG yields has a notable impact on the costs of SG custom establishment. The cost to have SG custom established increases by $381 thousand due to the increased SG acreage required associated with decreased expected yields. The costs of custom establishing SG for insurance increases by $294 thousand due to the increase in the required amount of land.

Total annual operating costs are estimated to be $40.30 million (table E28), representing a cost increase from the baseline of $1.62 million on an annual basis (table E26). Decreasing SG yields significantly increases the cost of leasing SG land and performing SG field operations. Due to the decrease in average SG yields per acre, the acreage required for SG production is increased by 18,997 acres and constitutes a cost increase of $427 thousand. The amount of land required for SG insurance is increased by 15,000 acres and constitutes an annual cost increase of $263 thousand. As a result of increased SG acreage, the cost of performing SG field operations is increased by $849 thousand.

Table E29 is a summary for Scenario 3A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Reductions in SG maximum-expected yields results in an increase in the costs to supply a 30-million gallon conversion facility as a result of increased custom establishment and annual operating costs due to increased SG acreage for production and insurance; and
- There is a minimal change in capital investments used for HES production and HES annual operating costs; thus, the increased costs are absorbed by the model increasing capital investments used for SG production, SG insurance acreage, and SG annual operating costs.

Sensitivity Scenario 3B: SG Yields to 6 Dry Tons per Acre

In this scenario, increasing the maximum-expected SG harvested yield from 3 to 6 dry tons per acre is the only variable changed from the baseline assumptions. This scenario thus evaluates the consequences of achieving SG yields approaching those reported in other areas (e.g., Mitchell, Vogel, and Sarath 2008). Increasing the expected SG harvested yield impacts (i.e., increases) the nutrient requirements (i.e., pounds of fertilizer nutrients per acre) of the biomass feedstock. Therefore, the pounds of fertilizer nutrients applied per acre are increased proportionate to the expected increased tonnage of biomass feedstock removed per acre. Tables E30, E31, E32, and E33 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $50.72 million, i.e., $1.6907 per gallon of fuel produced, $911.58 per harvested acre of HES and SG, and $126.81 per dry ton of the requisite 400,000 tons of biomass feedstock (table E30). Increasing SG yields to 6 dry tons per acre decreases the total annual supply costs by $2.88 million, i.e., by $0.0960 per gallon of fuel produced and $7.20 per dry ton (table E30)[148]**.** The costs per acre are increased by

[148] Such "simple" calculation can perhaps be misleading in that the underlying cause-effect relationship between changes in variable levels and resulting cost reductions may not be linear, due to the myriad of factors involved and the interactions among those factors. Thus, when a specific parameter is of intense interest, analyses involving smaller, more discrete increments are appropriate. For example, in this case, a series of scenarios consisting of 1, 2, 3, 4, 5, and 6 dry ton yields per acre would be appropriate.

$187.91 per acre due to less low-cost SG acreage being available to spread the capital ownership costs across.

A total of 313,405 dry tons of HES is produced on 36,858 acres while a total of 100,000 dry tons of SG is produced on 18,784 acres to meet the annual biomass feedstock needs of the conversion facility (table E30). Thus, the total amount of biomass feedstock produced is 413,405 dry tons on 55,642 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 8.50 dry tons per acre and 5.32 dry tons per acre, respectively. As expected, SG yield per acre increased, resulting in less acres of SG land being required to meet the conversion facility's periodic requirements. Due to the increase in maximum-expected SG yields, the amount of SG land established for insurance was decreased by 21,500 acres.[149]

The increase in SG yields also has a notable impact on the costs of SG custom establishment for production and SG insurance. The total requisite initial investment for the CBFFE is estimated to be $105.25 million while the cost on an annual basis is estimated to be $13.72 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E31), resulting in an annual cost increase of $1.20 million (table E30). An increase in SG maximum-expected yield has a substantial impact on required SG capital investments. The required number of machinery units purchased for both HES and SG field operations was reduced by 15 units, totaling an annual cost decrease of $296 thousand. SG machinery requirements are

[149] In the Year 2 Baseline Scenario, 40,000 acres of SG land is established for insurance purposes. In this scenario, 18,500 acres of SG land is established which is equivalent to approximately 25 percent of the conversion facility's yearly biomass feedstock needs. The decrease in insurance SG acreage was determined by dividing 100,000 dry tons by the average SG yield of 5.53 dry tons per acre across all 24 bi-weekly periods.

decreased by 14 units and HES machinery requirements are decreased by one unit. The cost to have SG custom established for production decreases by $369 thousand while the cost of custom establishing SG for insurance decreases by $437 thousand.

Total annual operating costs are estimated to be $37 million (table E32), representing a cost decrease from the baseline of $1.68 million on an annual basis (table E30). Increasing SG yields significantly decreases the cost of leasing SG land and performing SG field operations. The acreage required for SG production is decreased by 18,441 acres while the acreage required for SG insurance is decreased by 21,500 acres. Reducing SG acreage for production and insurance decreases annual operating costs by $415 thousand and $376 thousand, respectively. The reduction in SG acreage reduces the costs of performing SG field operations by $806 thousand.

Table E33 is a summary for Scenario 3B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Increases in SG maximum-expected yields result in decreased costs to supply a 30-million gallon conversion facility as a result of reduced custom establishment costs and lower annual operating costs due to reduced acreage; and

- The reduction in acreage reduces the SG custom establishment costs for production by $369 thousand while the cost of custom establishing SG for insurance decreases by $437 thousand.

Sensitivity Scenario 4A: HES Only

In this scenario, the only biomass feedstock produced by the CBFFE to supply the conversion facility for one year is HES. The maintenance of SG insurance acreage for 25 percent of the conversion facility's annual biomass feedstock requirements is included, however. Tables E34, E35, E36, and E37 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with only HES is $63.68 million, i.e., $2.1227 per gallon of fuel produced, $1,260.61 per harvested acre of HES, and $159.20 per dry ton of the requisite 400,000 tons of biomass feedstock (table E34). Producing a single biomass feedstock using HES increases the total annual supply costs by $10.08 million, by $0.3360 per gallon of fuel produced, by $536.94 per harvested acre, and by $25.19 per dry ton (table E34). Cost per acre increases due to HES being relatively more expensive than SG as a biomass feedstock source in the targeted locale.

A total of 429,844 dry tons of HES are produced on 50,515 harvested acres to meet the annual biomass feedstock needs of the conversion facility. The number of dry tons of HES produced increases by 116,578 dry tons (table E34). This increase in production is driven by the timing of the HES harvest and the subsequent model-user-defined periodic storage deterioration factor incorporated in Sorghasaurus©. As more biomass feedstock is harvested during the early harvest periods, the amount of biomass feedstock transferred from period to period increases, thus increasing the amount of biomass feedstock deterioration and reducing the overall quantity of the biomass feedstocks in storage. This results in more biomass feedstock needing to be harvested to meet periodic biomass feedstock requirements of the conversion facility over a 12-month operating cycle.

The total requisite initial investment for the CBFFE is estimated to be $137.71 million while the cost on an annual basis is estimated to be $17.65 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E35), resulting in an annual cost increase of $2.73 million (table E34). Producing only HES has a significant impact on machinery requirements, requiring a total of 110 more pieces of machinery (due to the more-intensive cultivation requirements of HES relative to SG). The required machinery for SG production is reduced by 65 units, totaling a costs reduction of $1.21 million. However, the increase in HES production, and the subsequent increase in HES acreage, increases the required HES machinery by 175 units. A total of 157 semi trucks and semi trailers are required (compared to 115 for the Year 2 Baseline Scenario) while the number of harvesters required increases to 18 (compared to 13 for the Year 2 Baseline Scenario). The increase in the number required for these two capital items results in an annual cost increase of $1.2 million and $456 thousand, respectively. A total of 101 irrigation wells are required (compared to 78 for the Year 2 Baseline Scenario), increasing annual costs by $491 thousand. The required number of re-lift pumps is increased to 337 (compared to 246 for the Year 2 Baseline Scenario), resulting in a cost increase of $150 thousand annually.

Total annual operating costs are estimated to be $46.03 million (table E36), representing a cost increase from the baseline of $7.34 million on an annual basis (table E34). Producing only HES significantly increases the cost of hiring full-time labor, irrigation, and harvesting. Producing only HES increases the cost of leasing HES land by $786 thousand; however, this cost increase is offset by the $838 thousand cost savings associated with reducing non-insurance SG acreage to zero.

The increase in HES acreage has a substantial impact on the costs of irrigation, planting, and harvesting due to the increase in the required amount of variable inputs (i.e., water, HES seed, fuel, etc.). Irrigation water requirements are increased by 227,882 acre-inches, resulting in a cost increase of $1.28 million. This increase in water requirements (occurring because of increased HES acreage) increases the overall number of irrigation wells required. A total of 12.12 million pounds of nitrogen, 4.04 million pounds of phosphorus, and 8.08 million pound of potassium are required, summing to 24.25 million pounds annually. Thus, the increased acreage associated with increased HES production increases the pounds of fertilizer nutrients required by 6.56 million pounds and constitutes a cost increase of $2.56 million a year.

Table E37 is a summary for Scenario 4A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Attempts to supply the conversion facility solely with regionally-grown HES biomass feedstocks production would be an expensive venture with current level of technology and the seasonality production constraints of the target study area; and
- The increase in HES acreage has a substantial impact on operating costs in the form of increased irrigation, planting, and harvesting activities due to the increase in the required amount of variable inputs.

Sensitivity Scenario 4B: SG Only

In this scenario, the only biomass feedstock produced by the CBFFE to supply the conversion facility for one year is SG. The maintenance of SG insurance acreage for 25 percent of the conversion facility's annual biomass feedstock requirements is included. Tables E38, E39, E40, and E41 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

This sensitivity scenario addresses the issue noted by Rooney (2011) regarding that the approach taken in this thesis research is the reverse of normal approach by others, i.e., they are using perennials (e.g., SG) as the base biomass feedstock source and annuals (e.g., HES) as insurance. This sensitivity analysis relying solely on SG as the source of biomass feedstock for a biofuel conversion facility is used to isolate and evaluate the point made by Rooney (2011). Interestingly, as noted below, the costs are lowered substantially by relying solely on SG (i.e., removing the Year 2 Baseline Scenario's 25 percent maximum restriction on SG as a source for the conversion facility), indicating the potential for HES in the targeted study area is questionable as depicted in the Year 2 Baseline Scenario. The purpose of the other sensitivity scenarios contained in this thesis are to explore under what conditions HES would be more competitive.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with only SG is $35.28 million, i.e., $1.1761 per gallon of fuel produced, $242.10 per harvested acre of SG, and $88.21 per dry ton of the requisite 400,000 tons of biomass feedstock (table E38). Producing only SG decreases the total annual supply costs by $18.32 million, by $0.6106 per gallon of fuel produced, by $481.57 per harvested acre, and by $45.80 per dry ton (table E38). Cost per acre decreases because more (and only) lower-cost SG acreage is included in the crop mix. That is, since the maximum-expected yield for SG is only 3 dry tons per acre (relative to the maximum-expected 12 dry tons of HES per acre), more acreage must be leased in order to produce the required 400,000 dry tons required by the conversion facility.

A total of 403,139 dry tons of SG are produced on 145,743 acres to meet the annual biomass feedstock needs of the conversion facility. Although the amount of land required increases by 108,518 acres, the number of dry tons of SG produced actually decreases by 10,127 dry tons (table E38). SG is allowed to be harvested during any time period which permits the model to determine the optimal amount of biomass feedstock to be harvested during any given period to reduce the required storage units and subsequent storage losses. The number of storage units required for this scenario is reduced by 92 units, totaling a savings of $901 thousand. Since the model is not restricted on the available number of harvest periods, as it is when harvesting HES, the model is able to minimize storage losses (and costs) by storing the SG in the field and harvesting it on an as needed basis for the most part. The ability to do so reduces storage losses and the subsequent amount of biomass feedstock that must be produced to supply the conversion facility with a year-round supply of biomass feedstock. It is noteworthy that all SG biomass feedstocks are not delivered on a “Just-In-Time” basis within this scenario, i.e., some storage does occur. This result occurs as a result of the anticipated field deterioration of SG during Nov B - Mar A (table D15) exceeding the expected periodic storage losses, thereby encouraging storage.

The total requisite initial investment for the CBFFE is estimated to be $81.68 million while the cost on an annual basis is estimated to be $8.46 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E39), resulting in an annual cost savings of $6.46 million (table E38). The most significant cost associated with producing SG is having the SG acreage custom established. The costs of this operation increase substantially due to the increase in the required SG acreage, i.e., increase of $2.38 million.

Producing only SG has a significant negative impact on machinery requirements, requiring a total of 376 less pieces of machinery. The required machinery for HES production is reduced by 439 units, totaling a costs reduction of $6.42 million. However, the increase in SG production and the subsequent increase in SG acreage, increases the required SG machinery by 63 units, totaling $1.14 million. A total of 35 semi trucks and semi trailers are required compared to 115 for the Year 2 Baseline Scenario. As noted earlier, SG is allowed to be harvested during any time period, which allows the model to spread out SG harvesting. Doing so significantly reduces the number of semi truck-trailer units required, saving $2.05 million annually. Since SG is not irrigated, the required numbers of irrigation wells and re-lift pumps are reduced to zero, totaling cost reductions of $1.66 million and $405 thousand, respectively.

Total annual operating costs are estimated to be $26.83 million (table E40), representing a cost decrease from the baseline of $11.85 million on an annual basis (table E38). Producing only SG significantly reduces the cost of hiring full-time labor, irrigation, performing HES field operations, and transportation. As noted in the Year 2 Baseline Scenario, full-time labor constitutes a substantial portion of total annual supply costs. The required number of full-time employees for this scenario are estimated to be 80 laborers. This constitutes a reduction of 90 laborers and a cost saving of $4.40 million. Producing only SG increases the cost of leasing SG land by $2.44 million; however, this costs increase is partially offset by the $2.12 million costs savings associated with reducing HES land (both cropped and in rotation) to zero. Since SG is farmed dryland (rainfed), the cost of irrigation is reduced to zero, reducing total annual costs $3.44 million. The costs of performing SG field operations for this scenario are estimated to be $13.37 million while the costs of transporting SG are $1.44 million. Producing only SG significantly reduces annual operating costs because all of the SG establishment operations are performed by custom operators once every ten years and the annual required field operations for SG are substantially less than required for HES[150]. The costs savings to the CBFFE associated with not performing HES field operations and transportation operations are $11.72 million and $2.26 million, respectively.

Table E41 is a summary for Scenario 4B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock

[150] SG field operations performed by the CBFFE include spraying, cutting, raking, and harvesting. HES field operations performed by the CBFFE include discing, land planing, bedding, hipping, fertilizing, spraying, conditioning beds, planting, cultivating, and harvesting.

(Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are:

- Although more land-intensive in nature (and thus highly dependent on no adverse changes in leased land costs), a monoculture of SG production as the sole source of biomass feedstock for the conversion facility is substantially less expensive than the baseline scenario’s reliance on both HES and SG (with SG constrained to a maximum of 25 percent of the supply);
- For the assumptions embedded in the baseline scenario for the targeted study area, using a perennial crop (e.g., SG) as the base source of biomass feedstock and an annual crop (e.g., HES) as insurance could potentially reduce the costs to supply a 30-million gallon per year conversion facility; and
- Although SG machinery and equipment requirements are increased, the increased capital outlay is offset by the large reduction in HES capital.

Sensitivity Scenario 5A: Capital Costs are Reduced 15 percent

In this scenario, decreasing capital costs by 15 percent is the only variable changed from the baseline assumptions. One interpretation of the rationale for this scenario is that substantial cost savings related to capital purchases might be forthcoming to the CBFFE because of its relatively-large size. Alternatively, some other organizational form of the business might conceivably allow for lower capital costs. Decreasing capital costs impacts the costs associated with purchasing machinery and equipment, the headquarters, irrigation wells, and storage facilities. Tables E42, E43, E44, and E45 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $51.35 million, i.e., $1.7116 per gallon of fuel produced, $695.17 per harvested acre of HES and SG, and $128.37 per dry ton of the requisite 400,000 tons of biomass feedstock (table E42). Decreasing capital costs by 15 percent reduces the total annual supply costs by $2.26 million, i.e., by $0.0751 per gallon of fuel produced, by $28.50 per harvested acre of HES and SG, and by $5.64 per dry ton (table E42).

A total of 313,044 dry tons of HES is produced on 36,611 acres while a total of 100,000 dry tons of SG is produced on 37,251 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,044 dry tons on 73,862 acres. For this sensitivity scenario, average HES

and SG yields equate to 8.55 dry tons per acre and 2.68 dry tons per acre, respectively (table E42). Reducing capital costs by 15 percent has little impact on HES and SG acreage and yields. The amount of HES acreage required is reduced by 234 acres while the amount of SG acreage is increased by 26 acres. HES average yields are increased by 0.05 dry tons per acre and SG yields are reduced by 0.01 dry tons per acre.

The total requisite initial investment for the CBFFE is estimated to be $101.25 million while the cost on an annual basis is estimated to be $12.79 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E43), resulting in an annual cost decrease of $2.13 million (table E42). Reducing capital investment costs lowers the cost of purchasing the headquarters by $133 thousand. Reducing capital investment costs also has a significant impact on the costs of purchasing machinery and equipment. Under this scenario, amortized machinery and equipment costs accounts for $7.16 million of the total costs, constituting a reduction of $1.14 million on an annual basis (table E43). The minimal reduction in HES wet ton production slightly reduces the amount of storage land, storage units, and silo covering required. Storage land is reduced by 40,960 sq-ft while the number of storage units and silo coverings are reduced one unit and 23,760 sq-ft, respectively. Together, the reduction in these three capital items reduces annual capital investment costs by $291 thousand.

Total annual operating costs are estimated to be $38.56 million (table E44), representing a cost decrease from the baseline of $125 thousand on an annual basis (table E42). Decreasing capital investment costs has little impact on annual operating costs, i.e., there are slight reductions due to the decrease in HES acreage and related decrease in HES production. The most notable reduction is on the costs of performing HES field operations which is reduced by $72 thousand. The majority of this cost reduction is attributed to fertilizing which is reduced by $44 thousand due to the decrease in HES acreage.

Table E45 is a summary for Scenario 5A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that overestimating capital investment costs by 15 percent is equivalent to a $5.64 cost per dry ton of biomass feedstock. Overestimating capital investment costs has a minimal effect on annual operating costs, reducing operating costs by $125 thousand, with such effects related to minor adjustments in biomass feedstock crop acreages and related agronomic activities.

Sensitivity Scenario 5B: Capital Costs are Increased 15 percent

In this scenario, increasing capital costs by 15 percent is the only variable changed from the baseline assumptions. The logic of this scenario relates to possible underestimation of the costs related to capital purchases in the Year 2 Baseline Scenario. Increasing capital costs impacts the costs associated with purchasing machinery and equipment, the headquarters, irrigation wells, and storage facilities. Tables E46, E47, E48, and E49 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $55.83 million, i.e., $1.8609 per gallon of fuel produced, $753.69 per harvested acre of HES and SG, and $139.56 per dry ton of the requisite 400,000 tons of biomass feedstock (table E46). Increasing capital costs by 15 percent increases the total annual supply costs by $2.22 million, i.e., by $0.0742 per gallon of fuel produced, by $30.02 per harvested acre of HES and SG, and by $5.55 per dry ton (table E46).

A total of 313,266 dry tons of HES is produced on 36,845 acres while a total of 100,000 dry tons of SG is produced on 37,225 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,266 dry tons on 74,070 acres. For this sensitivity scenario, average HES and SG yields equate to 8.50 dry tons per acre and 2.69 dry tons per acre, respectively (table E46). Increasing capital costs by 15 percent has no impact on HES and SG acreage or yields. This can be interpreted to mean that the manner in which the machinery is used in the Year 2 Baseline Scenario is optimal and purchasing machinery at increased costs does not affect the cost-minimizing production portfolio.

The total requisite initial investment for the CBFFE is estimated to be $135.72 million while the cost on an annual basis is estimated to be $17.14 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E47), resulting in an annual cost increase of $2.22 million (table E46). Increasing capital investment costs has little impact on the required number of capital investments. The only changes from the Year 2 Baseline Scenario are decreases in the amount of road base and the numbers of storage units, storage land, and silo coverings. The amount of road base is reduced by 188 square-feet while the numbers of storage units, storage land, and silo coverings are reduced by one unit, 40,960 square-feet, and 23,760 square-feet, respectively. Total annual operating costs are estimated to be $38.68 million (table E48). Increasing capital investment costs has no impact on annual operating costs (table E46).

Table E49 is a summary for Scenario 5B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that underestimating capital investment costs is equivalent to a \$5.50 cost per dry ton of biomass feedstock. The noted increase in capital investment costs has no effect on annual operating costs.

Sensitivity Scenario 5C: Operating Costs are Reduced 15 percent

In this scenario, decreasing operating costs by 15 percent is the only variable changed from the baseline assumptions. The perspective of this scenario is that there may be some economies of purchasing power associated with the CBFFE not represented in the Year 2 Baseline Scenario. Decreasing operating costs impacts the costs associated with procuring variable inputs (e.g., fertilizer, herbicides) and performing field operations, transportation, and storage operations. Tables E50, E51, E52, and E53 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $48.27 million, i.e., $1.6090 per gallon of fuel produced, $664.38 per harvested acre of HES and SG, and $120.68 per dry ton of the requisite 400,000 tons of biomass feedstock (table E50). Decreasing operating costs by 15 percent reduces the total annual supply costs by $5.33 million, i.e., by $0.1777 per gallon of fuel produced, by $59.29 per harvested acre of HES and SG, and by $13.33 per dry ton (table E50).

A total of 314,325 dry tons of HES is produced on 35,359 acres while a total of 100,000 dry tons of SG is produced on 37,297 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 414,325 dry tons on 72,656 acres. For this sensitivity scenario, average HES and SG yields equate to 8.89 dry tons per acre and 2.68 dry tons per acre, respectively

(table E50). A somewhat unexpected result is the increase in HES yields. As operating costs are reduced, tradeoffs between increased capital investments to allow for the harvest of more acreage during maximum-expected yield periods and reduced operating costs become economically advantageous. That is, as operating costs are reduced, more capital investments occur so as to allow for more acreage to be harvested and hauled during periods of higher-expected HES yields, thus, increasing the average HES yield per acre.

The total requisite initial investment for the CBFFE is estimated to be $123.41 million while the cost on an annual basis is estimated to be $15.35 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E51), resulting in an annual cost increase of $433 thousand (table E50). As discussed earlier, a decrease in operating costs has a somewhat unexpected result on capital investment costs. The most notable change is on the number of irrigation wells required. The required number of irrigation wells for this scenario is 93 (compared to 78 for the Year 2 Baseline Scenario), resulting in a cost increase of $320 thousand on an annual basis (table E51). In interpreting this result, one is reminded that the required number of irrigation wells is dependant on the number of acres planted during each respective planting period, the acre-inches applied per acre, and the irrigation restrictions per well, i.e., pumping capacity per period per irrigation well. Under this scenario, all 93 irrigation wells are used (i.e., there is no excess capacity) during the April A and April B periods to irrigate 9,985 acres during the April A period and 9,557 acres during the April B period. Under the Year 2 Baseline Scenario, all 78 irrigation wells are also used during the April A and April B periods; however, only 8.374 acres are irrigated during the April A period and only 8,016 acres are irrigated during the April B period. Thus, a total of 1,610 more acres must be irrigated during the April A and 1,541 more acres during the April B periods for this scenario than under the Year 2 Baseline Scenario. Multiplying the excess acres by 16.67 acre-inches and dividing by the irrigation well size 2 (2,500 GPM) pumping capacity limit for each respective period, results in an increase of 15 irrigation wells for this scenario[151]. It should be noted that according to the planting/harvest yield curve, maximum-expected HES yield of 12 dry tons per acre is only achieved by planting during the April A and April B planting periods. Thus, the increase in planted acreage during these two periods results in an increase in HES average yield and reduced HES acreage.

Total annual operating costs are estimated to be $32.92 million (table E52), representing a cost decrease from the baseline of $5.76 million on an annual basis (table E50). Reducing operating costs has an impact on all annual costs; however, the most notable reductions are on the costs of fertilizing, hiring full-time labor, irrigation, performing SG field operations, and leasing HES land. Under this scenario, a total of 8.49 million pounds of nitrogen, 2.83 million pounds of phosphorus, and 5.66 million pound of potassium are required, summing to 16.97 million pounds annually. The reduction in fertilizer nutrients requirements resulting from a reduction in HES planted acres and the reduction in fertilizer nutrients costs per acre constitutes a cost decrease of $1.27 million annually.

[151] The irrigation well size 2 (2,500 GPM) pumping capacity limit for April A is 1,789.8 acre-inches and the pumping capacity limit for April B is 1,713.1 acre-inches.

The required number of full-time employees hired for this scenario actually decreases, however, due to the 15 percent reduction in annual salaries; the costs for hiring the 180 full-time laborers is reduced by $832 thousand. Irrigation water requirements are reduced by 24,770 acre-inches due to the decrease in HES acreage, translating into a cost reduction of $619 thousand.

The costs of performing SG field operations for this scenario are reduced by $505 thousand. The required number of HES acres is reduced by 1,486 acres due to the increase in HES average yields. This reduction in acreage along with the 15 percent reduction in per acre lease cost results in a cost reduction of $390 thousand.

Table E53 is a summary for Scenario 5C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that as operating costs are reduced, the tradeoff between increased capital investments to allow for the harvest of more acreage during maximum-expected yield periods and reduced operating costs become economically advantageous. That is, as operating costs are reduced, more capital investments occur so as to allow for more acreage to be harvested and hauled during periods of higher expected HES yields, thus, increasing the average HES yield per acre.

Sensitivity Scenario 5D: Operating Costs are Increased 15 percent

In this scenario, increasing operating costs by 15 percent is the only variable changed from the baseline assumptions. The thought behind framing this scenario is that these costs are underestimated, for whatever reason, in the Year 2 Baseline Scenario. Increasing operating costs impacts the costs associated with procuring variable inputs (e.g., fertilizer, herbicides) and performing field operations, transportation, and storage operations. Tables E54, E55, E56, and E57 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $59.27 million, i.e., $1.9757 per gallon of fuel produced, $800.26 per harvested acre of HES and SG, and $148.17 per dry ton of the requisite 400,000 tons of biomass feedstock (table E54). Increasing operating costs by 15 percent increases the total annual supply costs by $5.67 million, i.e., by $0.1890 per gallon of fuel produced, by $76.59 per harvested acre of HES and SG, and by $14.26 per dry ton (table E54).

A total of 313,510 dry tons of HES is produced on 36,883 acres while a total of 100,000 dry tons of SG is produced on 37,180 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,510 dry tons on 74,063 acres. For this sensitivity scenario, average HES and SG yields equate to 8.50 dry tons per acre and 2.29 dry tons per acre, respectively

(table E54). Unlike sensitivity scenario 5C where decreasing operating costs had a significant impact on HES yields and capital investments, increasing operating costs has little effect on these two items.

The total requisite initial investment for the CBFFE is estimated to be $118.25 million while the cost on an annual basis is estimated to be $14.91 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E55), resulting in an annual cost increase of $9 thousand (table E54). The two most notable changes in capital investments in terms of costs are irrigation wells size 2 and HES disc, both increasing by one unit, resulting in cost increases of $21 thousand and $12 thousand, respectively. The amounts of storage land, storage units, and silo covering required are reduced due to timing of HES harvest. Storage land is reduced by 40,960 sq-ft while the number of storage units and silo coverings are reduced one unit and 23,760 sq-ft, respectively. Together, the reduction in these three capital items reduces annual capital investment costs by $13 thousand.

Total annual operating costs are estimated to be $44.36 million (table E56), representing a cost increase above the baseline of $5.68 million on an annual basis (table E54). Increasing operating costs has an impact on all annual costs; however, the most notable increases are on the costs of hiring full-time labor, irrigation, performing SG field operations, transporting HES, and fertilizing. The required number of full-time employees hired for this scenario does not change; however, due to the 15 percent increase in annual salaries, the cost for hiring the 170 full-time laborers is increased by $1.25 million. Irrigation water requirements are slightly increased by 638 acre-inches due to the 38-acre increase in HES land requirements. This increase along with the increase in annual operating costs increases irrigation costs by $505 thousand.

The cost of performing SG field operations for this scenario are increased by $506 thousand while the cost of transporting HES are increased by $338 thousand. Under this scenario, a total of 8.85 million pounds of nitrogen, 2.95 million pounds of phosphorus, and 5.90 million pound of potassium are required, summing to 17.70 million pounds annually which is 18 thousand pounds more than for the Year 2 Baseline Scenario. This increase in fertilizer nutrients requirements occurs because of increased HES planted acres and the increase in operating costs (e.g., costs per units of fertilizer nutrients) increases annual operating costs by $1.04 million (table E54).

Table E57 is a summary for Scenario 5D of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Increasing operating costs has the most substantial impact on the cost of fertilizing accounting for approximately 20 percent of the total costs increase; and
- Somewhat opposite of the results of reducing operating costs, the change in the amount of land required and biomass feedstock produced is minimal.

Sensitivity Scenario 5E: Capital Discount Rate is Reduced 1 percent

In this scenario, reducing the capital discount rate by one percent (i.e., from 5.75 percent to 4.75 percent is the only variable changed from the baseline assumptions. The capital discount rate is used when calculating the annuity equivalent costs of ownership (including insurance, property taxes, and fixed repairs) for capital investments; therefore, reducing this rate lowers the annual ownership costs of each purchased capital item. The cost of operating capital monies is maintained at an annual rate of 6.125 percent (adjusted to 2.55 percent reflecting operating funds are assumed invested/borrowed for five months of the year) in this scenario. Tables E58, E59, E60, and E61 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $52.92 million, i.e., $1.7641 per gallon of fuel produced, $714.74 per harvested acre of HES and SG, and $132.31 per dry ton of the requisite 400,000 tons of biomass feedstock (table E58). Reducing the capital discount rate by one percent reduces total annual supply costs by $679 thousand, i.e., by $0.0226 per gallon of fuel produced, by $8.93 per harvested acre of HES and SG, and by $1.70 per dry ton (table E58).

A total of 313,331 dry tons of HES is produced on 36,846 acres while a total of 100,000 dry tons of SG is produced on 37,200 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,331 dry tons on 74,046 acres. For this sensitivity scenario, average HES and SG yields equate to 8.50 dry tons per acre and 2.69 dry tons per acre, respectively (table E58). Reducing the capital discount rate has little impact on the number of HES and SG acres required and only slightly increases the required dry ton production.

The total requisite initial investment for the CBFFE is estimated to be $117.80 million while the cost on an annual basis is estimated to be $14.24 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E59), resulting in an annual cost decrease of $674 thousand (table E58). Reducing the capital discount rate increases machinery and equipment purchases by three units; however, the reduction in the capital discount rate offsets this increase and decreases the net costs of purchasing all machinery and equipment by $268 thousand. The required number of irrigation wells is reduced by three units, totaling a cost reduction of $213 thousand. The numbers of storage units, storage land, and silo coverings are reduced by one unit, 40,960 square-feet, and 23,760 square-feet, respectively, totaling a gross costs saving of $166 thousand.

Reducing the capital discount rate by one percent has little effect on annual operating costs. Total annual operating costs are estimated to be $38.68 million (table E60), representing a cost decrease from the baseline of $4 thousand on an annual basis (table E58). The only notable cost increase is on the costs to transport HES, which is reduced by $2 thousand. This reduction in transportation costs is driven by the decrease in the number of HES wet tons that must be transported.

Table E61 is a summary for Scenario 5E of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are:

- Choice of capital discount rate affects magnitude of annual capital costs and related bottomline cost per dry ton of delivered biomass feedstocks; and
- Reductions in the capital costs discount rate has a very minimal impact on annual operating costs.

Sensitivity Scenario 5F: Consider Only Farm-Gate Costs

In this scenario, only the farm gate costs are considered when determining the annual costs to supply a 30-million gallon a year conversion facility. That is, the costs associated with transporting (from the fields) and storing the HES and SG biomass feedstocks are removed from consideration and only the costs to the farm gate are determined. The intent of this sensitivity scenario is to emphasize the production and harvesting segments of the logistics chain, isolating them from the impacts of transportation and storage considerations. Tables E62, E63, E64, and E65 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $34.72 million, i.e., $1.1573 per gallon of fuel produced, $518.36 per harvested acre of HES and SG, and $86.80 per dry ton of the requisite 400,000 tons of biomass feedstock (table E62). Removing the costs of transportation and storage reduces the total annual supply costs by $18.89 million, i.e., by $0.6294 per gallon of fuel produced, by 205.31 per harvested acre of HES and SG biomass feedstock, and by $47.21 per dry ton (table E62).

A total of 315,906 dry tons of HES is produced on 30,980 acres while a total of 100,000 dry tons of SG is produced on 35,998 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 415,906 dry tons on 66,978 acres. For this sensitivity scenario, average HES

and SG yields equate to 10.20 dry tons per acre and 2.78 dry tons per acre, respectively (table E62). Removing the transportation and storage operation substantially increases HES and SG yields, which in turn reduces the required HES and SG acreage by 5,865 acres and 1,227 acres, respectively. The increase in HES and SG yields can be attributed to the removal of the transportation operation and the costs thereof as the transportation operation was constrained by the same trafficable days availability as all other field operations. That is, removing transportation allows for the harvest of more acreage during time periods with higher-potential maximum yields because the costs and trafficability constraints associated with transportation are removed. Restated, consideration of minimizing transportation costs is not an added factor influencing harvest decisions in this scenario.

The total requisite initial investment for the CBFFE is estimated to be $73.25 million while the cost on an annual basis is estimated to be $9.26 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E63), resulting in an annual cost estimate that is $5.66 million lower than for the holistic logistics biomass feedstock supply system (table E62). Semi truck and HES trailer units purchases are totally eliminated (a reduction of 115 units), resulting in a cost reduction of $2.65 million. Similarly, SG flatbed semi trailers purchases are eliminated (a reduction of 20 units), translating into an annual cost reduction of $87 thousand. Purchases of HES and SG storage handling units are also eliminated (reductions of 34 and 5 units, respectively), resulting in annual cost reductions of $563 thousand and $141 thousand, respectively. Purchases of storage bunkers are eliminated (a reduction of 148 units) are the purchases of storage land and silo coverings (decreases of 6,062,080 square-feet and 3,516,480 square-feet, respectively). Together, the elimination of purchasing these three items (i.e., $1.45 million, $189 thousand, and $231 thousand) results in annual cost savings of $1.87 million.

Due to the decrease in the number of HES acres, machinery purchases (excluding semi trucks and HES and SG flatbed semi trailers) are reduced by 16 units, totaling a savings of $658 thousand on an annual basis. The reduction in HES acreage also reduces the required number of irrigation wells and re-lift pumps by 10 wells and 39 re-lift pumps, resulting in annual cost reductions of $213 thousand and $64 thousand, respectively.

Total annual operating costs are estimated to be $25.46 million (table E64), representing a $13.22 million reduction on an annual basis from the Year 2 Baseline Scenario (table E62). As noted in the Year 2 Baseline Scenario, hiring full-time labor constitutes a large portion of total annual costs and the majority of the laborers are required for transportation. Removing transportation and storage requirements reduces the required number of full-time hires by 130 people and constitutes reduction in annual operating costs of $6.36 million. The costs associated with transporting and storing HES and SG biomass feedstock are reduced by $2.26 million and $353 thousand, respectively.

Due to the increase in HES and SG average harvested yields per acre, the required acreage for HES and SG production is reduced by 5,865 acres and 1,227 acres, respectively (table E62). This reduction in acreage has a substantial impact on the costs of irrigation and fertilizing due to the reduction in the required amount of variable inputs (i.e., water, HES seed, fuel, etc.). Irrigation water requirements are reduced by 97,762 acre-inches, resulting in a cost savings of $547 thousand.

As noted in the Year 2 Baseline Scenario, fertilizing constitutes a substantial portion of total annual supply costs. Under this scenario, a total of 7.44 million pounds of nitrogen, 2.48 million pounds of phosphorus, and 4.96 million pound of potassium are required, summing to 14.87 million pounds annually. The increased HES yields and subsequent reduction in HES acreage reduces fertilizer nutrients requirements by 2.82 million pounds and constitutes a cost decrease of $1.10 million a year.

Table E65 is a summary for Scenario 5F of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from analyzing this scenario are:

- Optimal cost estimates are substantially affected by the perspective taken in the analysis. If one were to simply take the Year 2 Baseline Scenario optimal solution of $134.01 cost per dry ton of biomass feedstock and eliminate the transportation and storage components costs of $14.77 and $4.68 per dry ton, respectively, the estimated farm-gate cost per dry ton would be $114.56. Such an estimate is markedly different than that derived for this scenario (i.e., $86.80 per dry ton), underscoring the importance of understanding the point of view represented in publically-cited cost estimates for biomass feedstock production;

- Beyond the farmgate costs account for more than 35 percent of the delivered costs of supplying a conversion facility with biomass feedstock – alternatively, production and harvest of the biomass feedstock represent just under 65 percent of the cost; and
- Removing the transportation and storage operations substantially increases HES and SG yields, which in turn reduces the required HES and SG acreage as more acreage can be harvested during time periods with higher potential maximum yields because the costs and trafficability constraints associated with transportation are removed.

Sensitivity Scenario 5G: Consider Only "Just-In-Time" Deliveries

This scenario focuses on identifying the cost effects of biomass feedstock storage and periodic deterioration. In this scenario, only "Just-In-Time" deliveries of HES and SG biomass feedstocks are considered (i.e., no biomass feedstocks are stored and there is no biomass feedstock deterioration[152]). SG production is unrestricted in this scenario (i.e., as opposed to the maximum 25 percent of requirements assumed in the Year 2 Baseline Scenario) and is allowed to contribute any amount to the conversion facility's total annual biomass feedstock requirements. Tables E66, E67, E68, and E69 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $56.05 million, i.e., $1.8683 per gallon of fuel produced, $513.97 per harvested acre of HES and SG, and $140.12 per dry ton of the requisite 400,000 tons of biomass feedstock (table E66). A somewhat unexpected result is that by allowing only "Just-In-Time" deliveries, the total annual supply costs are increased by $2.45 million, i.e., by $0.0816 per gallon of fuel produced and by $6.11 per dry ton. The costs per acre decrease due to more (i.e., a greater proportion of) SG acreage being included in the production portfolio. However, the per ton and per gallon costs increase as a result of having to invest in more machinery and equipment to harvest and transport

[152] Since all deliveries are "Just-In-Time", there is no carryover of biomass feedstocks from period to period (except for the three periods worth of insurance reserves), thus eliminating the majority of physical deterioration of stored biomass feedstocks).

biomass feedstocks during those time periods with below-average, limited numbers of trafficable days, i.e., in the Year 2 Baseline Scenario, biomass feedstocks could be harvested in other periods, stored, and used in such periods whereas in this scenario, those possibilities are nonexistent.

A total of 167,556 dry tons of HES is produced on 19,199 acres while a total of 232,444 dry tons of SG is produced on 89,851 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 400,000 dry tons on 109,050 acres. Relative to the 25 percent maximum SG supplies allowed in the Year 2 Baseline Scenario, SG accounts for 58.11 percent in this scenario. For this sensitivity scenario, average harvested HES and SG yields equate to 8.73 dry tons per acre and 2.59 dry tons per acre, respectively. The decreased dependance on HES reduces the required acreage by 17,646 acres while SG acreage is increased by 52,626 acres (table E66).

The total requisite initial investment for the CBFFE is estimated to be $122.88 million while the annual cost basis is estimated to be $16.14 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E67), resulting in an annual cost increase of $1.22 million (table E66). The two main costs components driving the increase in capital expenditures are the costs of purchasing machinery and equipment and the costs to custom establish SG land. The total numbers of machinery and equipment required are increased by 180 units, totaling $2.63 million. Due to the substantial increase in SG acreage and the inability to store from one period to subsequent periods, the required machinery and equipment purchases for SG production increase by 94 units, not including semi trucks and SG flatbed semi trailers. Notable increases in SG machinery are with respect to purchasing bale wagons, hay squeezes, and hay cutters. The requisite number of bale wagons increases by 25 units while the required numbers of hay squeezes and hay cutters increase by 19 units and 11 units, respectively, totaling annual cost increases of $774 thousand, $534 thousand, and $300 thousand, respectively.

For similar reasons, the required numbers of semi trucks, HES end-dump semi trailers, and SG flatbed semi trailers increase by 50 units, 50 units, and 30 units, respectively, totaling annual costs increases of $857 thousand, $295 thousand, and $131 thousand, respectively. Although HES production in total decreases, the number of HES end-dump semi trailers and semi trucks purchased increases because more tonnage per day is required to be harvested and hauled during some periods in which there are limited trafficable days. Due to the substantial decline in HES acreage, the required numbers of irrigation wells and re-lift pumps are decreased by 44 wells and 118 pumps. The decrease in the required number of these two items results in annual capital cost decreases of $938 thousand and $194 thousand, respectively.

It is assumed that no biomass feedstocks are stored and carried over for subsequent use; however, it is assumed that what biomass feedstock is produced during any given period is temporarily stored during that period in the same manner as in the Year 2 Baseline Scenario. Thus, while some minimal biomass feedstock storage infrastructure is maintained in this scenario, the total number of storage bunkers and the amounts of storage land and silo coverings required are reduced by 130 units, 5,324,800 square-feet, and 3,088,800 square-feet, respectively, totaling annual cost decreases of $1.27 million, $166 thousand, and $203 thousand, respectively. The increase in SG acreage increases the annual costs of custom establishing SG land by $1.15 million.

Total annual operating costs are estimated to be $39.91 million (table E68), representing an annual $1.23 million increase relative to the Year 2 Baseline Scenario (table E66). Allowing only "Just-In-Time" deliveries of biomass feedstock has a substantial impact on the number of full-time employees hired. The number of full-time employees hired is increased by 80 laborers and constitutes an increase in annual operating costs of $3.91 million. The increase in the number of full-time employees hired is due to more tonnage being harvested each period (to meet "Just-In-Time" delivery constraints) that must be transported to the conversion facility. Due to the increase in SG acreage, the cost of performing SG field operations is increased by $4.74 million while the cost of transporting SG is increased by $132 thousand. The required number of HES acres is reduced by 17,646 acres (table E66), constituting an annual cost reduction of $1.01 million.

Due to the decline in HES acreage, the costs of pumping groundwater and performing HES field operations are reduced. The amount of irrigation water applied decreases by 294,161 acre-inches, reducing the cost of pumping groundwater by $1.65 million. The cost of performing HES field operations is reduced by $5.60 million. The most notable reductions are in the costs of fertilizing, harvesting, and planting HES. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by $3.35 million. A total of 4.61 million pounds of nitrogen, 1.54 million pounds of phosphorus, and 3.07 million pound of potassium are required, summing to 9.22 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $3.30 million. The costs of harvesting and planting HES are reduced by $929 thousand and $704 thousand, respectively. Due to the decline in the amount of HES wet tonnage, the costs of transporting HES are reduced by $1.03 million.

Table E69 is a summary for Scenario 5G of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- The per ton and per gallon costs increase as a result of having to invest in more machinery and equipment to harvest and transport biomass feedstocks during those time periods with below-average limited trafficable days, i.e., in the baseline scenario, biomass feedstocks could be harvested in other periods, stored, and used in such periods – in this scenario, that is not possible; and
- Allowing "Just-In-Time" deliveries substantially increases the required number of full-time labor hires as a result of more tonnage being harvested each period (to meet "Just-In-Time" delivery constraints) that must be transported to the conversion facility.

Sensitivity Scenario 5H: Consider Only "Just-In-Time" Deliveries with Average Trafficable Days

In this scenario, similar to scenario 5G, only "Just-In-Time" deliveries of HES and SG biomass feedstocks are considered (i.e., no biomass feedstocks are stored and there is no biomass feedstock deterioration[153]). SG biomass feedstock production is unrestricted in this scenario and allowed to contribute any amount to the conversion facility's total annual biomass feedstock requirements. An added feature of consideration beyond that of scenario 5G is that trafficable days remain set at the 75 percent probability level, but each period's trafficable hours are averaged with the period before and the period after, i.e., effectively representing a "smoothing" of available field time, removing to some extent the extreme ranges inherent in the observed historical data. Tables E70, E71, E72, and E73 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $52.58 million, i.e., $1.7528 per gallon of fuel produced, $482.72 per harvested acre of HES and SG, and $131.46 per dry ton of the requisite 400,000 tons of biomass feedstock (table E70). Allowing only "Just-In-Time" deliveries and averaging the trafficable days reduces the total annual supply costs by $1.02 million, i.e., $0.0339 per gallon of fuel produced, $240.95 per harvested acre, and $2.55 per dry ton.

[153] Since all deliveries are "Just-In-Time", there is no carryover of biomass feedstocks from period to period (except for the three periods worth of insurance reserves), thus eliminating the majority of physical deterioration of stored biomass feedstocks.

A total of 167,556 dry tons of HES is produced on 19,080 acres while a total of 232,444 dry tons of SG is produced on 89,851 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 400,000 dry tons on 108,931 acres. Relative to the 25 percent maximum SG supplies allowed in the Year 2 Baseline Scenario, SG accounts for 42 percent in this scenario. For this sensitivity scenario, average HES and SG yields equate to 8.78 dry tons per acre and 2.59 dry tons per acre, respectively. The decreased dependance on HES reduces the required acreage by 17,765 acres while SG acreage is increased by 52,626 acres (table E70).

The total requisite initial investment for the CBFFE is estimated to be $102.61 million while the cost on an annual basis is estimated to be $12.72 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E71), resulting in an annual cost increase of $2.20 million (table E70). The three main components driving the decrease in capital expenditures are the reductions in the costs of purchasing machinery and equipment, irrigation wells, and storage bunkers. The total number of machinery and equipment units required is decreased by 37 units, totaling $581 thousand. Due to the substantial increase in SG acreage, the required machinery and equipment purchases for SG production increase by 59 units. The most notable increases in SG machinery is with regards to the costs of purchasing bale wagons, hay squeezes, and hay cutters. The requisite number of bale wagons increases by 15 units while the required number of hay squeezes and hay cutters increases by 11 units and 7 units, respectively, totaling annual cost increases of $464 thousand, $309 thousand, and $191 thousand. The reduction in HES acreage decreases the required number of HES machinery by 96 units, totaling $1.73 million. The most notable reductions are in the costs of purchasing HES harvesters, tractors size 1 (225 hp), and planters. The number of HES harvesters required is reduced by 7 units while the numbers of tractors size 1 (225 hp) and planters required are reduced by 11 units and 4 units, respectively, totaling annual capital cost reductions of $638 thousand, $363 thousand, and $151 thousand, respectively. Due to the substantial decline in HES acreage, the required number of irrigation wells and re-lift pumps is decreased by 42 wells and 118 pumps. The decrease in the required number of these two items results in annual capital cost decreases of $896 thousand and $194 thousand, respectively. It is assumed that no biomass feedstocks are stored and carried over for later use; however, it is assumed that what biomass feedstock is produced during any given period is stored in the same manner as in the Year 2 Baseline Scenario. Thus, the total number of storage bunkers and the amounts of storage land and silo coverings required are reduced by 130 units, 5,324,800 square-feet, and 3,088,800 square-feet, respectively, totaling an annual cost decreases of $1.27 million, $166 thousand, and $203 thousand. The increase in SG acreage increases the costs of custom establishing SG land by $1.15 million.

Total annual operating costs are estimated to be $39.86 million (table E72), representing a $1.18 million increase on an annual basis from the Year 2 Baseline Scenario (table E70). Due to the increase in SG acreage, the costs of performing SG field operations is increased by $4.74 million while the costs of transporting SG is increased by $468 thousand due to the increase in SG production. The number of full-time laborers required is increased by 80 employees and constitutes an annual costs increase of $3.91 million. The required number of HES acres is reduced by 17,765 acres and constitute an annual costs reduction of $1.02 million.

Due to the decline in HES acreage, the costs of pumping groundwater and performing HES field operations are significantly reduced. The decrease in HES acreage reduces the amount of irrigation water required by 296,149 acre-inches and decreases the costs of pumping groundwater by $1.66 million. The costs of performing HES field operations are reduced by $5.64 million due to the decline in HES acreage. The most notable reductions are on the costs of fertilizing, harvesting and planting HES. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by $3.37 million.

A total of 4.58 million pounds of nitrogen, 1.53 million pounds of phosphorus, and 3.05 million pound of potassium are required, summing to 9.16 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $3.33 million. The costs of harvesting and planting HES are reduced by $933 thousand and $709 thousand, respectively. Due to the decline in the amount of HES wet tonnage that must be transported, the cost of transporting HES is reduced by $1.03 million.

In comparing the results of scenario 5H to those for scenario 5G, the smoothing of trafficable days had the most significant impact on the required numbers of semi-trucks and trailers required for HES and SG transportation. Overall, the required numbers of machinery and equipment used for HES and SG production was reduced from 721 pieces for scenario 5G to 504 pieces for scenario 5H; a reduction of 217 pieces totaling a costs savings of $3.21 million.

Table E73 is a summary for Scenario 5H of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that imposing "Just-In-Time" delivery requirements while relaxing the constraint of only 25 percent of the biomass feedstock supply being sourced from SG and considering some smoothing in availability of periodic trafficable days had some, but mostly negligible, effect on delivered biomass feedstock costs per dry ton, particularly when compared to the results of scenario 5G.

Sensitivity Scenario 5I: No Full-Time Labor (Only Part-Time)

In this scenario, only part-time labor is used to perform all HES and SG field operations, transportation, and storage operations; that is, no full-time labor is employed for these activities. The supposition of this scenario is that much of the labor requirements are seasonal in nature and the Year 2 Baseline Scenario's requirements of largely a full-time labor contingent may be cost prohibitive. The issue of availability of an adequate quantity/supply of part-time labor in the targeted production area is acknowledged, but ignored, in this analysis. Since part-time labor is hired on an as needed basis and are paid an hourly wage instead of a full-time employee salary, costs are only incurred when labor is actively engaged in operations. Tables E74, E75, E76, and E77 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $47.79 million, i.e., $1.5931 per gallon of fuel produced, $708.21 per harvested acre of HES and SG, and $119.48 per dry ton of the requisite 400,000 tons of biomass feedstock (table E74). Allowing part-time labor (instead of requiring full-time labor) to perform any farming operation reduces the total annual supply costs by $5.81 million, i.e., by $0.1936 per gallon of fuel produced, by $15.46 per harvested acre of HES and SG biomass feedstock, and by $14.53 per dry ton (table E74).

A total of 314,404 dry tons of HES is produced on 31,301 acres while a total of 100,000 dry tons of SG is produced on 36,184 acres to meet the annual biomass

feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 414,404 dry tons on 67,485 acres. For this sensitivity scenario, average HES and SG yields equate to 10.04 dry tons per acre and 2.76 dry tons per acre, respectively. Providing unrestricted part-time labor hours substantially increases HES and SG yields, which in turn reduces the required HES and SG acreage by 5,544 acres and 1,041 acres, respectively. The increase in HES and SG yields can be attributed to more acreage being harvested during periods of higher-expected maximum yields because the costs incurred by allowing unrestricted part-time labor is less prohibitive than the costs of hiring additional full-time employees.

The total requisite initial investment for the CBFFE is estimated to be $129.02 million while the cost on an annual basis is estimated to be $16.33 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E75), resulting in an annual cost increase of $1.41 million (table E74). The increase in HES wet ton production results from more acreage being harvested during the early harvest periods, thus increasing the amount of biomass feedstock that is transferred from period to period, and subsequently increasing the amount of biomass feedstock deterioration and reducing the overall quality of the biomass feedstocks in storage. This increase in wet ton production increases the number of semi truck and HES trailer units purchased by 39 units, resulting in an annual cost increase of $899 thousand. The increase in HES wet ton production also impacts the number of tractors size 2 (152 hp), HES storage handling machines, and in-field buggies required. The number of tractors size 2 (152 hp) required increases by 21 units while the number of HES storage handling machines and in-field buggies required increases by 11 units and 13 units, respectively, resulting in cost increases of $453 thousand, $182 thousand, and $75 thousand, respectively. The number of storage units required and the amount of storage land and silo coverings required are increased by 21 units, 860,160 square-feet, and 498,960 square-feet, respectively, resulting in annual cost increases of $206 thousand, $27 thousand, and $33 thousand. The required number of irrigation wells for HES is increased by 2 wells, totaling an annual cost increase of $43 thousand. Although a decrease in HES acreage would suggest a decrease in the required number of irrigation wells, the amount of acreage planted during the seven planting periods is consolidated into fewer periods (the periods with the highest-expected HES yields) and more acreage is planted during each of these periods. This occurrence increases the number of irrigation wells as more acreage must be irrigated in a shorter amount of time than under the Year 2 Baseline Scenario.

Total annual operating costs are estimated to be $31.47 million (table E76), representing a $7.22 million reduction on an annual basis from the Year 2 Baseline Scenario (table E74). Allowing unrestricted part-time labor totally eliminates the required number of full-time hires by 170 people, reducing annual operating costs by $8.32 million. A total of 333,814 hours of part-time labor is required, totaling $4.50 million (table E76). Thus, the reduction in labor costs from the Year 2 Baseline Scenario by allowing part-time labor to perform any CBFFE operation (from production through storage) is $4.36 million.

Due to the increase in HES and SG average yields per acre, the required acreage for HES and SG production is reduced by 5,544 acres and 1,041 acres, respectively (table E74). This reduction in acreage has a substantial impact on the costs of irrigation and the costs of performing HES field operations. Irrigation water requirements are reduced by 92,411 acre-inches, resulting in a cost savings of $517 thousand while the costs of performing HES field operations is reduced by $1.65 million. The most notable reduction in the costs of performing HES field operations is on the costs of fertilizing which are reduced by $1.05 million. Under this scenario, a total of 7.51 million pounds of nitrogen, 2.50 million pounds of phosphorus, and 5 million pound of potassium are required, summing to 15.02 million pounds annually. The increased HES average yields and subsequent reduction in HES acreage reduces fertilizer nutrients requirements by 2.66 million pounds and constitute a cost decrease of $1.04 million annually.

Table E77 is a summary for Scenario 5I of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are:

- Assumption of availability of and reliance on part-time labor (as opposed to mostly full-time labor) lowered delivered biomass feedstock costs by 10.8 percent (by $14.53 per dry ton); and

- Realized HES and SG yields substantially increased due to more acreage being harvested during periods of higher-expected maximum yields because the costs incurred by allowing unrestricted part-time labor is less prohibitive than the costs of hiring additional full-time employees.

Sensitivity Scenario 5J: Lease All Transportation (versus Purchased)

In this scenario, allowing all semi trucks and HES and SG flatbed semi trailers to be leased instead of purchased are the only variables changed from the Year 2 Baseline Scenario. Assuming/provided adequate supplies of semi trucks and semi trailers for lease/hire are available (e.g., akin to the season availability of cotton module trucks throughout the cotton belt as cotton harvest progresses), this scenario is a reasonable consideration for a business depending on substantial seasonality in its transportation needs. Allowing all transportation equipment to be leased significantly reduces the initial capital investments and annualized purchase costs. Tables E78, E79, E80, and E81 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $51.90 million, i.e., $1.7294 per gallon of fuel produced, $709.33 per harvested acre of HES and SG, and $129.71 per dry ton of the requisite 400,000 tons of biomass feedstock (table E78). Allowing all transportation equipment to be leased reduces the total annual supply costs by $1.70 million, i.e., by $0.0573 per gallon of fuel produced, by $14.34 per harvested acre of HES and SG biomass feedstock, and by $4.30 per dry ton (table E78).

A total of 313,233 dry tons of HES is produced on 35,847 acres while a total of 100,000 dry tons of SG is produced on 37,297 acres to meet the annual biomass feedstock needs of the conversion facility (table E78). Slight acreage adjustments (998 less HES acres and 72 more SG acres) occur in response to adjustments in the calculated periodic costs of transporting the biomass feedstocks. Thus, the total amount of biomass feedstock produced is 413,233 dry tons on 73,144 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 8.74 dry tons per acre and 2.68 dry tons per acre, respectively (table E78).

The total requisite initial investment for the CBFFE is estimated to be $98.56 million while the costs on an annual basis are estimated to be $12 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E79), resulting in an annual cost decrease of $2.92 million (table E78). Allowing transportation equipment to be leased instead of purchased reduces the number of semi trucks and HES end-dump semi trailers purchased by 115 units. The number of SG flatbed semi trailers required is reduced by 20 semi trailers, totaling a costs savings of $87 thousand. Reducing the amount of machinery and equipment purchased reduces the costs of purchasing pole barns for machinery storage by $48 thousand. Due to the decrease in the amount of HES land required, the number of HES harvesters required is reduced by 2 units, totaling an annual cost decrease of $182 thousand.

Total annual operating costs are estimated to be $39.89 million (table E80), representing a $1.20 million increase on an annual basis from the Year 2 Baseline Scenario (table E78). The most notable increase is in the costs of transporting HES and SG biomass feedstocks. The costs of leasing the transportation equipment for HES and

SG (considered to be an operating cost item) is estimated to be $1.14 million[154]. Under the Year 2 Baseline Scenario, the annual transportation operating costs for HES and SG biomass feedstocks is estimated to be $2.26 million and $353 thousand, respectively. In this scenario, the operating costs for HES transportation is reduced by $10 thousand while the operating costs for SG is unchanged. Thus, leasing transportation equipment increases total annual operating costs by $1.13 million. However, the source of this apparent substantial increase originates with the leasing costs for semi trucks and semi trailers being considered an annual operating cost, whereas in the Year 2 Baseline Scenario, a major cost factor (not present in this scenario) is the capital investment cost associated with purchasing the semi trucks and semi trailers. If capital investment costs of $2.74 million were combined with the operating costs for the Year 2 Baseline Scenario, leasing HES and SG transportation equipment would reduce costs by $1.60 million.

Due to the increase in HES average harvested yields, the amount of HES acreage is decreased by 998 acres (table E78), representing an annual cost decrease of $57 thousand. The decrease in HES acreage decreases the amount of irrigation water required by 16,629 acre-inches, reducing the cost of pumping groundwater by $93 thousand. The decrease in HES acreage also decreases the costs of performing all HES field operations by $293 thousand. The increase in the amount of wet tonnage that must

[154] Daily lease rates were derived by dividing the annuity equivalent costs of ownership (including insurance, property taxes, and fixed repairs) by the sum of trafficable days at the 75 percent probability level and then multiplying that calculated value by 1.10, with the extra 10 percent representing an arbitrarily-assumed leasing company premium. It is assumed that the semi trucks and HES and SG flatbed semi trailers are utilized by other businesses either locally or in other locations when not required by the CBFFE.

be transported increases the number of full-time labor hires by 10 employees, constituting an annual cost increase of $489 thousand.

Table E81 is a summary for Scenario 5J of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that leasing of transportation trucks and trailers only during those periods in which they are used as opposed to year-round ownership has negligible impact on costs, i.e., a reduction of 3.2 percent – by $4.30 per dry ton. It is appropriate to note that such results are contingent on the assumptions made in calculating the lease rates for the transportation trucks and trailers relative to their outright purchase costs.

Sensitivity Scenario 5K: Periodic Storage Deterioration Increased to 5.0 percent

The degree of biomass feedstock deterioration that will occur during storage is uncertain at best for the humid conditions of the Middle Gulf Coast, Edna-Ganado, Texas area. In this scenario, the Year 2 Baseline Scenario storage loss assumption of one percent per period is increased to five percent per period, representing what is perceived to be an extreme loss scenario. Increasing biomass feedstock deterioration while in storage impacts the amount of biomass feedstock that must be harvested to meet annual biomass feedstock needs of the conversion facility. Tables E82, E83, E84, and E85 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $62.35 million, i.e., $2.0784 per gallon of fuel produced, $786.53 per harvested acre of HES and SG, and $155.88 per dry ton of the requisite 400,000 tons of biomass feedstock (table E82). Increasing biomass feedstock deterioration increases the total annual supply costs by $8.75 million, i.e., by $0.2917 per gallon of fuel produced, by $62.86 per harvested acre of HES and SG biomass feedstock, and by $21.87 per dry ton (table E82).

A total of 372,955 dry tons of HES is produced on 42,598 acres while a total of 100,000 dry tons of SG is produced on 36,677 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 472,955 dry tons on 79,275 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 8.76 dry tons per acre and 2.73 dry tons per acre, respectively (table E82). An increase in HES and SG yields suggests a decrease in HES and SG acreage; however, the increase in biomass feedstock storage deterioration increases the amount of biomass feedstock that must be harvested, thus increasing the acreage required to supply 400,000 dry tons to the conversion facility. Under the Year 2 Baseline Scenario, a total of 13,266 dry tons of biomass feedstock was lost during storage. Under this scenario, a total of 72,955 dry tons of biomass feedstock is lost in storage, thus increasing the amount of wet tonnage required to be harvested by 59,689 dry tons (170,010 wet tons).

The total requisite initial investment for the CBFFE is estimated to be $137.05 million while the annual costs are estimated to be $17.68 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E83), resulting in an annual cost increase of $2.76 million (table E82). The increase in biomass feedstock deterioration and the related increase in HES acreage increase the total numbers of machinery and equipment required by 117 units, totaling an annual capital cost increase of $1.95 million. The increase in wet ton harvested production increases the number of semi truck and HES trailer units required by 27 units, resulting in an annual cost increase of $622 thousand. The increase in HES wet ton production and the subsequent increase in HES acreage also impact the required number of HES harvesters, tractors size 2 (152 hp), tractors size 1 (225 hp), and HES storage handling machines. The number of HES harvesters is increased by 4 units while the number of tractors size 2 (152 hp) required is increased by 10 units, totaling annual cost increases of $365 thousand and $216 thousand, respectively. The required numbers of tractors size 1 (225 hp) and HES storage handling machines are increased by 5 units and 10 units, respectively, totaling annual increases of $165 thousand and $166 thousand. The number of storage units required and the amount of storage land and silo coverings required are increased by 26 units, 1,064,960 square-feet, and 617,760 square-feet, respectively, resulting in annual cost increases of $255 thousand, $33 thousand, and $41 thousand. The required number of irrigation wells for HES is increased by 11 wells in response to the increased acreage, totaling an annual cost increase of $235 thousand.

Total annual operating costs are estimated to be $44.67 million (table E84), representing a $5.98 million annual increase relative to the Year 2 Baseline Scenario (table E82). The most notable increase is in the number of full-time employees hired. The increase in the amount of biomass feedstock that must be transported and the subsequent increase in the number of semi trucks and HES end-dump semi trailers increases the required number of full-time employees hired by 50 laborers, constituting an increase in annual operating costs of $2.45 million.

Due to the increase in the amount of wet tonnage that must be harvested, the amount of HES acreage is increased by 5,753 acres, representing an annual cost increase of $331 thousand. The increase in HES acreage increases the amount of irrigation water required by 95,899 acre-inches, increasing the costs of pumping groundwater by $537 thousand. The increase in HES acreage also increases the costs of performing all HES field operations by $1.85 million

The most notable increase in the costs of performing HES field operations is in the costs of fertilizing. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, increase by $1.09 million. A total of 10.22 million pounds of nitrogen, 3.20 million pounds of phosphorus, and 6.40 million pound of potassium are required, summing to 21.38 million pounds annually. This increase in amount of fertilizer nutrients required increases the costs of purchasing fertilizer nutrients by $809 thousand. Due to the substantial increase in the amount of HES wet tonnage that must be transported, the costs of transporting HES is increased by $406 thousand.

Table E85 is a summary for Scenario 5K of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that the level of assumed storage deterioration of biomass feedstock is an important cost consideration as each additional percent storage loss results in a per dry ton increase of $5.34 (in this scenario) as the amount of land, variable inputs, and capital investments required must be increased in response to the heightened demand.

Sensitivity Scenario 5L: Periodic Storage Deterioration Increased to 0.2 percent

In this scenario, decreasing storage losses from one percent per period to 0.2 percent per period is the only variable changed from the Year 2 Baseline Scenario; i.e., 24 periods times 0.2 percent equals 4.8 percent, approximating the annual 5.0 percent reported by Hess, Wright, and Kenney (2007). Decreasing biomass feedstock deterioration while in storage reduces the amount of biomass feedstock that must be harvested to meet annual biomass feedstock needs of the conversion facility. Tables E86, E87, E88, and E89 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $51.80 million, i.e., $1.7268 per gallon of fuel produced, $693.52 per harvested acre of HES and SG, and $129.51 per dry ton of the requisite 400,000 tons of biomass feedstock (table E86). Decreasing biomass feedstock deterioration decreases the total annual supply costs by $1.80 million, i.e., by $0.0599 per gallon of fuel produced, $30.15 per harvested acre of HES and SG biomass feedstock, and by $4.50 per dry ton (table E86).

A total of 303,269 dry tons of HES is produced on 36,553 acres while a total of 100,000 dry tons of SG is produced on 38,154 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 403,269 dry tons on 74,698 acres. For this sensitivity scenario, average HES and SG yields equate to 8.30 dry tons per acre and 2.62 dry tons per acre, respectively

(table E86). Although the calculated reduction HES yields (i.e., by 0.2 dry tons per acre) would suggest increased HES acreage, the decrease in biomass feedstock storage deterioration reduces the amount of required biomass feedstock that must be grown and harvested, thus decreasing the acreage required to supply 400,000 dry tons to the conversion facility. The decrease in biomass feedstock yields is attributed to the model harvesting more biomass feedstock during periods of lower maximum-expected yields. This result occurs because of the tradeoff between purchasing more machinery and equipment to harvest more biomass feedstock per acre during periods of maximum-expected HES yields when the fewest trafficable hours are available. Under the Year 2 Baseline Scenario, a total of 13,266 dry tons of biomass feedstock was lost in storage. Under this scenario, a total of 3,269 dry tons of biomass feedstock is lost in storage, thus decreasing the amount of wet tonnage harvested by 22,739 wet tons.

The total requisite initial investment for the CBFFE is estimated to be $112.81 million while the cost on an annual basis is estimated to be $13.90 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E87), resulting in an annual cost decrease of $1.02 million (table E86). The decrease in biomass feedstock deterioration and the related decrease in HES acreage reduces the total numbers of machinery and equipment required by 52 units, totaling an annual capital cost decrease of $912 thousand. The decrease in the numbers of machinery and equipment required is also attributed to field operations being performed on more acreage during times of increased trafficable hours.

The decrease in wet ton production decreases the number of semi truck and HES trailer units purchased by 6 units, resulting in an annual cost decrease of $138 thousand. The decrease in HES acreage and the fact that field operations are performed during periods with more trafficable hours impact the required number of HES harvesters and tractors size 1 (225 hp). The number of HES harvesters is decreased by 2 units while the number of tractors size 1 (225 hp) is decreased by 3 units, totaling an annual decrease in capital ownership costs of $182 thousand and $99 thousand, respectively. The number of bale wagons and hay squeezes for SG are decreased by 6 units and 5 units, respectively, reducing total annual capital investment costs by $186 thousand and $141 thousand. These decreases are due to SG harvest being performed over more periods as the decrease in storage deterioration allows biomass feedstock to be stored for a longer period of time with less losses. Thus, less acreage is harvested per period which reduces the required number of bale wagons and hay squeezes. The number of storage units required and the amount of storage land and silo coverings required are decreased by 4 units, 163,840 square-feet, and 95,040 square-feet, respectively, resulting in annual cost increases of $39 thousand, $5 thousand, and $6 thousand.

Total annual operating costs are estimated to be $37.91 million (table E88), representing a $773 thousand decrease on an annual basis from the Year 2 Baseline Scenario (table E86). The most notable decrease is on the number of full-time employees hired. The decrease in the amount of biomass feedstock that must be transported and the subsequent decrease in the number of semi trucks and HES end-dump semi trailers reduce the required number of full-time employees hired by 10 laborers, constituting a reduction in annual operating costs of $489 thousand.

Due to the decrease in the amount of wet tonnage that must be harvested, the amount of HES acreage is decreased by 292 acres, representing an annual cost decrease of $17 thousand. The decrease in HES acreage reduces the amount of irrigation water required by 4,860 acre-inches and reduces the costs of pumping groundwater by $27 thousand. The decrease in HES acreage also decreases the costs of performing all HES field operations by $106 thousand. The decrease in the amount of HES wet tonnage that must be transported reduces the costs of transporting HES by $58 thousand. The increase in the amount of SG land increases the costs of leasing SG land by $21 thousand and increases the costs of performing SG field operations by $67 thousand.

Table E89 is a summary for Scenario 5L of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that reductions in the assumed level of storage deterioration have an almost identical proportional decrease in per dry ton costs as did increases in the level of storage deterioration have on increases in cost per dry ton.

Sensitivity Scenario 6A: Trafficable Days Set at 50 Percent

Trafficable days represent the number of days available for work during a specific time period. The probability level specification for this sensitivity scenario is interpreted to reflect that, on average over an extended number of years, there is a 50 percent probability of having at least the designated number of days available for work compared to the 75 percent probability assumed for the baseline. In other words, the 75 percent trafficable days in the baseline can be interpreted as a 75 percent confidence level that the specified days for each time period are available, at a minimum, for field work. In this sensitivity scenario involving the more relaxed assumption of only a 50 percent probability levels, a greater number of days are assumed available in each time period. The number of trafficable days available per period directly impacts the required number of machinery units required to perform a field operation during the given period. Table D8 in Appendix D is a comparison of the number of field days and work hours specified as available for the three probability levels of trafficable days considered in this study – 50, 70, and 90 percent. The impact of assuming trafficable days at a 50 percent probability level is evaluated in this scenario. Tables E90, E91, E92, and E93 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is \$45.69 million, i.e., \$1.5231 per gallon of fuel produced, \$653.83 per harvested acre of HES and SG, and \$114.24 per dry ton of the requisite

400,000 tons of biomass feedstock (table E90). Increasing the expected number of trafficable days reduces the total annual supply costs by \$7.91 million, i.e., by \$0.2636 per gallon of fuel produced, by \$69.84 per harvested acre of HES and SG biomass feedstock, and by \$19.77 per dry ton (table E90).

Increasing the number of trafficable days considered available provides more working hours during each period, thus allowing more acreage to be harvested during periods of higher-expected yields. HES average yields are increased by 0.79 dry tons per acre, resulting in a reduction in HES acres of 3,131 acres (table E90). The reduction in HES acreage constitutes a cost reduction of \$409 thousand on an annual basis. Irrigation well requirements are reduced by 14 units due to the reduction in HES acreage, constituting a reduction in costs of \$299 thousand. The reduction in HES acreage reduces water requirements by 118,444 acre-inches and reduces pumping costs by \$663 thousand.

The increase in expected number of trafficable days significantly impacts (i.e., reduces) the required capital investments. Total initial capital investment costs are estimated to be \$98.61 million while costs on an annual basis are estimated to be \$11.74 million (table E91); a reduction of \$3.17 million on an annual basis (table E90). Machinery and equipment requirements are reduced by 183 units totaling a reduction in costs of \$2.66 million.

The required number of semi truck trailer units is reduced by 37 units, translating into a costs savings of \$853 thousand. The required number of harvesters and tractors size 1 (225 hp) are reduced by 4 units and 11 units, respectively. These results constitute reductions in costs of $634 thousand for the harvesters and $363 thousand for tractors size 1 (225 hp). The increase in trafficable days allows more acreage to be harvested during periods of higher maximum-expected yields and allows machinery and equipment to operate for a longer period of time during a given period, thus reducing the need to acquire additional machinery and equipment units to perform a given field operation or transportation operation at the determined optimal time period.

The reduction in acreage and the reduction in the required number of capital units reduces the costs of the headquarters by $268 thousand. The reduction in machinery and equipment decreases the square footage of the barns for machinery storage by 40,041 square feet, reducing costs by $246 thousand. The reduction in acreage reduces the required office space by 418 square feet, totaling a cost reduction of $11 thousand. The costs of road base and storage land are reduced by $10 thousand and $1 thousand, respectively.

A total of 941,757 wet tons are harvested for this sensitivity scenario. This sensitivity scenario requires the same number of storage units as the Year 2 Baseline Scenario, resulting in no capital costs reduction. The assumption of lowering the probability of trafficable field days from 75 to 50 percent and thereby increasing the number of field days and work hour capacities of all machinery units allows for lowering capital cost investments, but also represents an increase in risk, i.e., there is a lower confidence level that the number of days will actually be available.

Table E93 is a summary for Scenario 6A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that the increase in trafficable days significantly reduces the costs per dry ton (i.e., $19.77 per dry ton) by allowing more acreage to be harvested during periods of higher maximum-expected yields and allowing machinery and equipment to operate for a longer period of time during a given period, thus reducing the need to acquire additional machinery and equipment units to perform a given field operation or transportation operation at the determined optimal time period. Thus, the increase in the assumed level of trafficable days increases average HES yield per acre by 0.76 dry tons and reduces capital investment costs and annual operating costs by $7.94 per dry ton and $11.84 per dry ton, respectively.

Sensitivity Scenario 6B: Trafficable Days Set at 90 percent

For the Year 2 Baseline Scenario, table D8 in the Appendix D is a comparison of the number of field days and work hours specified as available for the three probability levels of trafficable days considered in this study – 50, 70, and 90 percent. Trafficable days represent the number of days available for work during a specific time period. The number of trafficable days available per period directly impacts the required number of machinery units required to perform a field operation during the given period. In this scenario, a more conservative approach is presumed than is the case in the Year 2 Baseline Scenario, attempting to ensure that adequate machinery and equipment resources are available for all production, harvests, and transportation operations within relatively "tight" windows of allowed field trafficability, i.e., fewer days are available for field related operations. The probability level specification for this scenario is interpreted to reflect that, on average over an extended number of years, there is a 90 percent probability of having at least the designated number of days available for work. Tables E94, E95, E96, and E97 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area with HES and SG biomass feedstocks under this assumption is $67.75 million, i.e., $2.2582 per gallon of fuel produced, $846.60 per harvested acre of HES and SG, and $169.36 per dry ton of the requisite 400,000 tons of biomass feedstock (table E94). Decreasing the number of trafficable days increases the total annual supply costs by $14.14 million, i.e., by $0.4715 per gallon of fuel produced, by $122.93 per harvested acre of HES and SG biomass feedstock, and by $35.35 per dry ton (table E94).

A total of 317,016 dry tons of HES is produced on 41,240 acres while a total of 100,000 dry tons of SG is produced on 38,780 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 417,016 dry tons on 80,020 acres. For this sensitivity scenario, average HES and SG yields equate to 7.69 dry tons per acre and 2.58 dry tons per acre, respectively (table E94). Decreasing the number of trafficable days reduces HES and SG yields, which in turn increases the required HES and SG acreage by 4,395 acres and 1,555 acres, respectively. The decrease in HES and SG yields can be attributed to decreasing trafficable days which provides less working hours during each period, thus allowing less acreage to be harvested during periods of higher-expected yields.

The total requisite initial investment for the CBFFE is estimated to be $153.02 million while the cost on an annual basis is estimated to be $20.98 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E95), resulting in an annual cost increase of $6.06 million (table E94). Decreasing the number of trafficable days available each period significantly impacts the number of machinery and equipment purchased. A total of 350 more pieces of machinery and equipment must be purchased, resulting in an annual cost increase of $5.29 million. The most notable increase is in the number of semi trucks and end-dump semi trailers purchased for HES transportation. The number of semi truck and HES trailer units purchased is increased by 75, resulting in a cost increase of $1.73

million. The number of HES harvesters purchased is increased by 7 units, translating into a cost increase of $638 thousand. The required numbers of tractors size 1 (225 hp) and tractors size 2 (152 hp) are increased by 17 units and 32 units, respectively, resulting in annual costs increases of $562 thousand and $690 thousand, respectively.

Total annual operating costs are estimated to be $46.76 million (table E96), representing a $8.08 million increase on an annual basis from the Year 2 Baseline Scenario (table E94). As noted in the Year 2 Baseline Scenario, hiring full-time labor constitutes a large portion of total annual costs. Reducing the number of trafficable days available each period increases the required number of full-time labor hires by 100 people and constitutes an increase in annual operating costs of $4.89 million. Due to the decrease in HES and SG average harvested yields per acre, the required acreage for HES and SG production is increased by 4,395 acres and 1,555 acres, respectively (table E94). This increase in acreage has a substantial impact on the costs of irrigation and fertilizing due to the increase in the required amount of variable inputs (i.e., water, HES seed, fuel, fertilizer, etc.). Irrigation water requirements are increased by 73,272 acre-inches, resulting in a cost increase of $410 thousand. Under this scenario, a total of 9.9 million pounds of nitrogen, 3.3 million pounds of phosphorus, and 6.6 million pound of potassium are required, summing to 19.8 million pounds annually. The reduced HES harvested yields, and subsequent increase in HES acreage, increases fertilizer nutrients requirements by 2.11 million pounds, representing an annual cost increase of $823 thousand.

Table E97 is a summary for Scenario 6B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that the more conservative approach assumed in this scenario regarding availability of trafficable days significantly increases the costs per dry ton (i.e., $35.35 per dry ton); that is, attempting to ensure that adequate machinery and equipment resources are available for all production, harvest, transportation, and storage operations within a relatively "tight" window of allowed field trafficability is costly. The reduction in trafficable days reduces average HES yield per acre by 0.81 dry tons and increases capital investment and annual operating costs by $15.15 per dry ton and $20.20 per dry ton, respectively. Thus, once can conclude that by taking a static modeling approach and not accounting for the "real world" trafficability issues, the assumed optimal cost per dry ton represented by extrapolating enterprise budgets can over/under-estimate true costs.

Sensitivity Scenario 6C: Only SG Grown With Trafficable Days Set at 90 percent

In this scenario, SG is the only biomass feedstock produced and supplied by the CBFFE to the conversion facility. Trafficable days are set at the 90 percent probability level (instead of the 75 percent probability level assumed in the Year 2 Baseline Scenario), which is interpreted to mean that on average, there is a 90 percent probability of having at least the designated number of days available for work. Thus, this scenario is a combination of scenarios 4B and 6B. Tables E98, E99, E100, and E101 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $41.02 million, i.e., $1.3675 per gallon of fuel produced, $281.41 per harvested acre of SG, and $102.56 per dry ton of the requisite 400,000 tons of biomass feedstock (table E98). As noted in sensitivity scenario 4B, producing only SG biomass feedstock reduces the total annual supply costs when compared to producing a mixed portfolio of HES and SG biomass feedstock. However, reducing the number of trafficable days assumed available for work with certainty has the opposite effect and increases requisite capital investment and operating costs. Under this scenario, the total annual supply costs are decreased by $12.58 million, i.e., by $0.4192 per gallon of fuel produced, by $442.26 per harvested acre, and by $31.45 per dry ton (table E98). Cost per acre decreases because more lower-cost SG acreage is included in the crop mix. That is, since the maximum-expected yield for SG is only 3 dry tons per acre, more acreage must be leased in order to produce the required 400,000 dry tons required by the conversion facility.

A total of 404,504 dry tons of SG are produced on 145,780 acres to meet the annual biomass feedstock needs of the conversion facility (table E98). Although the amount of land required increases by 108,555 acres, the number of SG dry tons produced actually decreases by 8,762 dry tons. SG is allowed to be harvested during any time period, which permits the model to determine the optimal amount of biomass feedstock to be harvested during any given period to reduce the required storage units and storage losses. The number of storage units required for this scenario is reduced by 74 units, totaling a savings of $725 thousand. Since the model is not restricted on the available number of harvest periods, as it is when harvesting HES, the model is able to minimize storage losses by storing the SG in the field and harvesting it on an as needed basis.

The total requisite initial investment for the CBFFE is estimated to be $96.76 million while the cost on an annual basis is estimated to be $11.12 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E99), resulting in an annual cost savings of $3.80 million (table E98). The most significant cost associated with producing SG is having the SG acreage custom established. The cost of this operation increases substantially due to the increase in the required SG acreage, increasing by $2.38 million.

Producing only SG significantly eliminates the numerous HES machinery requirements; however, the reduction in the number of trafficable days and the increase in SG acreage increases the number of SG machinery and equipment requirements. The required machinery for HES production is reduced/eliminated by 415 units, totaling costs reduction of $6.02 million. The reduction in trafficable days and the increase in SG acreage increases the required SG machinery by 159 units, however, totaling a cost increase of $2.97 million. A total of 60 semi trucks and semi trailers are required compared to 115 for the Year 2 Baseline Scenario. As noted earlier, SG is allowed to be harvested during any time period, allowing the model to spread out SG harvesting. This occurrence significantly reduces the number of semi truck-trailer units required, saving $1.45 million annually[155]. Since SG is not irrigated, the required number of irrigation wells and re-lift pumps is reduced to zero, totaling cost reductions of $1.66 million and $405 thousand, respectively.

Total annual operating costs are estimated to be $29.90 million, representing a cost decrease from the baseline of $8.78 million on an annual basis (table E100). Producing only SG significantly reduces the cost of hiring full-time labor, irrigation, performing HES field operations, and transportation. As noted in the Year 2 Baseline Scenario, full-time labor constitutes a substantial portion of total annual supply costs. The required number of full-time employees for this scenario are estimated to be 130 laborers. This constitutes a reduction of 40 laborers and an annual cost savings of $1.96 million annually. Producing only SG increases the cost of leasing SG land by $2.44 million; however, this cost increase is partially offset by the $2.12 million cost savings associated with reducing HES land to zero. Since SG is farmed under dryland (rainfed)

[155] This costs savings includes the reduction of 55 semi trucks and 115 HES trailers, totaling $1.62 million. The number of SG trailers is increased by 40 units, totaling an annual costs increase of $175 thousand. Thus, the annual costs saving of producing only SG biomass feedstock is $1.45 million.

conditions (i.e., is not irrigated), the costs of irrigation are reduced to zero, reducing total annual costs \$3.44 million. The costs of performing SG field operations for this scenario are estimated to be \$13.34 million while the costs of transporting SG to the conversion facility are estimated to be \$1.43 million. This constitutes cost increases of \$9.99 million and \$1.08 million, respectively, for performing SG field operations and transporting SG to the conversion facility.

Unlike HES, SG is a perennial crop and only has to be established once every ten years[156]. This factor is considered to be one of the main reasons that producing SG is less expensive than producing HES. Although the costs of custom establishing SG land, performing SG field operations, and transporting SG increase by \$2.38 million, \$9.99 million, and \$1.08 million, respectively, the costs savings to the CBFFE associated with not performing HES field operations and HES transportation operations are \$11.74 million and \$2.24 million, respectively. Thus, the net saving to the CBFFE in this scenario is \$537 thousand.

Table E101 is a summary for Scenario 6C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and

[156] SG field operations performed by the CBFFE include spraying, cutting, raking, and harvesting. HES field operations performed by the CBFFE include discing, land planing, bedding, hipping, fertilizing, spraying, conditioning beds, planting, cultivating, and harvesting.

the interpretation provided above are that unlike HES, SG is a perennial crop and only has to be established once every ten years and requires minimal subsequent annual agronomic operations which are main factors driving the reduction in total-delivered biomass feedstock costs. When compared to producing only SG under the baseline assumption, the costs per dry ton increases by $14.35. Thus, although more expensive than under the SG only baseline assumptions due to the restricted trafficable days assumption in this scenario, the costs of supplying a conversion facility with solely a perennial biomass feedstock reduces costs.

Sensitivity Scenario 6D: Trafficable Days Relaxed (75 Percent Probability Level x10)

In this scenario, trafficable days are set at the 75 percent probability level and then multiplied tenfold. The intent of this scenario is to eliminate/minimize the consideration of machinery and equipment constraints. That is, by assuming the noted substantial tenfold expansion of days and hours available for each machinery and equipment unit, this scenario, in effect, assumes area producers will "subsidize" purchased units with addition resources at no capital ownership costs. Tables E102, E103, E104, and E105 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $44.94 million, i.e., $1.4980 per gallon of fuel produced, $620.62 per harvested acre of HES and SG, and $112.35 per dry ton of the requisite 400,000 tons of biomass feedstock (table E102). Relaxing the number of trafficable days available decreases total annual supply costs by $8.66 million, i.e., by $0.2887 per gallon of fuel produced, by $103.05 per harvested acre, and by $21.66 per dry ton (table E102).

A total of 311,939 dry tons of HES is produced on 35,810 acres while a total of 100,000 dry tons of SG is produced on 36,600 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 411,939 dry tons on 72,410 acres. For this sensitivity scenario, average HES

and SG yields equate to 8.71 dry tons per acre and 2.73 dry tons per acre, respectively (table E102).

The total requisite initial investment for the CBFFE is estimated to be $72.11 million while the annual cost is estimated to be $7.01 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E103), resulting in an annual cost decrease of $7.91 million (table E102). Increasing the number of trafficable days available each period significantly impacts the required number of machinery and equipment purchased. A total of 469 less pieces of machinery and equipment must be purchased, resulting in an annual cost decrease of $7.08 million. The most notable decrease is in the number of semi trucks and end-dump and flatbed semi trailers purchased for HES and SG transportation. The number of semi truck and HES trailer units purchased is reduced by 103 units, resulting in an annual costs decrease of $2.37 million. The number of SG flatbed semi trailers is reduced by 17 units, totaling an annual cost decrease of $74 thousand. The numbers of HES harvesters and in-field buggies purchased are decreased by 11 units and 44 units, respectively, translating into cost reductions of $1 million and $254 thousand, respectively. The required numbers of tractors size 1 (225 hp) and tractors size 2 (152 hp) are decreased by 16 units and 33 units, respectively, resulting in annual cost savings of $529 thousand and $711 thousand, respectively.

Total annual operating costs are estimated to be $37.93 million (table E104), representing a $751 thousand annual decrease relative to the Year 2 Baseline Scenario (table E103). The minimal reduction in HES and SG acreage does not reduce operating costs significantly. The reduction in acreage has the most impact on the costs of fertilizing, pumping groundwater, and hiring part-time labor. The costs of fertilizing is reduced by $196 thousand on an annual basis. Under this scenario, the total amount of irrigation water required is reduced by 17,250 acre-inches, totaling a cost reduction of $97 thousand.

Table E105 is a summary for Scenario 6D of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that by minimizing the consideration of machinery and equipment constraints and assuming area producers will “subsidize” purchased units with addition resources at no capital ownership costs, the per dry ton biomass feedstock costs is reduced by $21.66. Thus, assuming that area producers will and can utilize the machinery and equipment for other crops, the ownership costs to the CBFFE can be substantially reduced.

Sensitivity Scenario 6E: Economics of Farm Size, with No SG and No Insurance

In this scenario, the impacts of having several single producers instead of one corporate farming entity is evaluated. A farm size capable of annually producing 2,500 acres of HES is targeted in this scenario. The only biomass feedstock produced under this scenario is HES; that is, no SG is produced for either production or insurance. Assuming average harvested HES yields of 8.5 dry tons per acre, each such traditional commercial farm would produce 21,500 dry tons of biomass feedstock (on a contractual basis), resulting in the need for 18.6 such farms.

The results reported for this scenario are for one of several single-farming entities supplying a 30-million gallon per year conversion facility. As is the case for the baseline and all other sensitivity scenarios, integer programming requirements are imposed on the purchase of all capital machinery, equipment, and transportation assets. The perceived issue that will arise as a result of several "smaller" commercial farms in comparison to the larger CBFFE entity is that there will be more idle, unused capital resources, resulting in higher costs per dry ton of required biomass feedstock. The results for this scenario are presented as one single-farming entity and then are multiplied by 18.60 to realize a total comparable to the Year 2 Baseline Scenario results (as this is the number of single-farming entities required to supply 400,000 dry tons of biomass feedstock annually). Tables E106, E107, E108, and E109 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual supply costs in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $5.62 million, i.e., $3.49 per gallon of fuel produced,[157] $2,252.70 per harvested acre of HES, and $261.52 per dry ton of the requisite 21,500 tons of biomass feedstock per single-farming entity (table E106)[158]. Producing biomass feedstocks under a single farming entity structure, increases the cost per gallon of fuel by $1.7003, the costs per acre by $1,529.03, and the costs per dry ton by $127.51 (table E106).

The total requisite initial investment for the CBFFE is estimated to be $7.58 million while the cost on an annual basis is estimated to be $1.07 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E107). Thus, the total initial capital investment and annualized costs to supply a 30-million gallon conversion facility with 400,000 dry tons of biomass feedstocks are $141.09 million and $19.95 million, respectively, resulting in an annual cost increase of $5.03 million (table E106). Producing biomass feedstock under the single-farming entity structure significantly impacts the required number of machinery and equipment purchased. A total of 819 pieces of machinery and equipment must be purchased for HES production compared to 476 units for the Year 2 Baseline Scenario. These additional capital purchases increase the costs of purchasing HES machinery and equipment by $5.61 million. The most notable increase is in the number of semi trucks

[157] Cost per gallon of fuel was derived by total annual costs by the biomass feedstock needs of the conversion facility (21,500 dry tons) multiplied by 75 gallons per dry ton.
[158] The amount of biomass feedstock required by the conversion facility from each single-farming entity was derived by multiplying 2,500 acres by the Year 2 Baseline Scenario average HES yields of 8.50 dry tons per acre.

and end-dump semi trailers purchased for HES transportation. The number of semi truck and HES trailer units purchased is increased by 71 units, resulting in an annual cost increase of $1.64 million. Other notable increases include the numbers of sprayers, tractors size 1 (225 hp), HES harvesters, planters, and tractors size 2 (152 hp) which are increased by 18 units, 16 units, 6 units, 12 units, and 19 units, respectively. The costs increases associated with the increased requirements for these five machinery and equipment items are $700 thousand, $536 thousand, $511 thousand, $438 thousand, and $406 thousand, respectively.

Total annual operating costs are estimated to be $4.55 million for each individual farming entity; thus, for the 18.6 single-farming entities required to supply a 400,000 dry tons conversion facility, total operating costs are estimated to be $84.66 million. This represents a $38.69 million increase from the Year 2 Baseline Scenario of $45.97 million. A total of 46,437 acres would be required to supply 400,000 dry tons of feedstock to the conversion facility which increases costs from the baseline year 2 scenario by $551 thousand. Producing feedstocks under the single-farming structure increases the amount of feedstock that must be transported to the conversion facility. A total of 1,277,083 wet tons of feedstock must be transported to the conversion facility compared to 950,719 for the baseline year 2 scenario. This substantial increase in the amount of feedstock that must be transported increases the costs of transportation costs by $2.0 million.

Table E109 is a summary for Scenario 6E of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that consideration of smaller farm sizes in the magnitude of 2,500 acres as opposed to the baseline scenario's assumed large-scale corporate farming entity resulted in almost doubling the delivered biomass feedstock costs (from \$134.01 to \$261.52 per dry ton of biomass feedstock, an increase of 95.1 percent).

Sensitivity Scenario 6F: Maximum HES Harvest Moisture Set at 25 percent

In this scenario, reducing the harvested HES moisture content to 25 percent is the only variable changed from the Year 2 Baseline Scenario[159]. The rationale for this scenario is that it evaluates the effects of the possibility of spraying a dessication agent on the HES to reduce harvest moisture content and lessen subsequent HES-only transportation costs**.** However, the potential implications of such treatment on conversion efficiency are not evaluated in this scenario. Tables E110, E111, E112, and E113 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $46.41 million, i.e., $1.5471 per gallon of fuel produced, $644.83 per harvested acre of HES and SG, and $116.03 per dry ton of the requisite 400,000 tons of biomass feedstock (table E110). Reducing the HES moisture content decreases total annual supply costs by $7.19 million, i.e., by $0.2396 per gallon of fuel produced, by $78.74 per harvested acre, and by $17.98 per dry ton (table E110).

A total of 315,901 dry tons of HES is produced on 35,168 acres while a total of 100,000 dry tons of SG is produced on 36,810 acres to meet the annual biomass feedstock needs of the conversion facility (table E110). Thus, the total amount of biomass feedstock produced is 415,901 dry tons on 71,978 acres. For this sensitivity

[159] The average harvested moisture content of HES under the Year 2 Baseline Scenario is 71.7 percent. With the harvest moisture reduced to 25 percent in this scenario, reductions in capital asset purchases of 41 semi trucks and 41 end-dump trailers occur.

scenario, average HES and SG yields equate to 8.98 dry tons per acre and 2.72 dry tons per acre, respectively (table E110). Reducing the HES moisture content increases HES and SG yields (because transportation was not as restrictive, making higher-yielding harvest periods more attractive), thus reducing the required HES and SG acreage by 1,677 acres and 415 acres, respectively.

The total requisite initial investment for the CBFFE is estimated to be $104.37 million while the cost on an annual basis is estimated to be $12.83 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E111), resulting in an annual cost decrease of $2.09 million (table E110). Reducing the harvested HES moisture content significantly impacts the required number of HES semi truck and units purchased. The number of semi trucks and trailer units is reduced by 41 units, totaling a reduction in annual capital costs of $945 thousand. The reduction in the number of semi truck and trailer units purchased is a direct result of the reduction in HES moisture content as the number of wet tons that must be transported to the conversion facility is reduced by 592,698 wet tons.

Reducing the HES moisture content also has a significant impact on the number of irrigation wells that must be purchased. The number of irrigation wells purchased is reduced by 12 wells, totaling an annual capital cost saving of $256 thousand. Reducing the amount of biomass feedstock that must be stored reduces the number of storage units required by 11 units and the amount of storage land and silo coverings by 450,560 square-feet and 261,360 square-feet, respectively[160]. The reduction in the number of

[160] An increase in the density of HES (i.e., lower harvest moisture) decreases the amount of storage space that one ton of biomass feedstock requires.

storage units totals an annual cost saving of $108 thousand while the reductions in the amount of storage land and silo covering reduce capital investment costs by $14 thousand and $17 thousand, respectively.

Total annual operating costs are estimated to be $33.59 million (table E112), representing a $5.10 million decrease on an annual basis from the Year 2 Baseline Scenario (table E110). The most notable reduction in operating costs relates to the number of full-time employees hired. As noted earlier, 170 full-time laborers constitute a large portion of annual operating costs, with the greatest proportion of the laborers (i.e., 40.63 percent) used for transportation (figure E1). The number of full-time employees hired is reduced by 50 laborers, constituting a reduction in annual operating costs of $2.45 million. In this scenario, transportation laborers are reduced to only represent 26 percent of the total laborers (figure E2). The reduction in HES moisture content significantly reduces the number of transportation trucks required and the amount of wet tonnage that must be hauled, thus reducing the number of laborers required to drive trucks. The reduction in the moisture content of HES also has a substantial impact on the costs to transport the biomass feedstock. HES transportation costs for fuel, repairs, and maintenance are reduced by $816 thousand, directly correlated to the reduction in the number of wet tons that are harvested.

The reduction in HES and SG acreage reduces the costs of performing HES and SG field operations by $823 thousand and $30 thousand, respectively. The most notable reductions in the costs of performing HES field operations are in regards to the costs of harvesting and fertilizing. The costs of performing the harvesting operation are reduced by $379 thousand while the costs of fertilizing are reduced by $318 thousand.

Table E113 is a summary for Scenario 6F of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that assuming development of a "free, magic bullet" which allows for the reduction of considerable excess harvest moisture in the HES biomass feedstock results in $17.98 per dry ton reduction in the delivered cost of biomass feedstock. Although the reduction in HES moisture content does result in a lower delivered biomass feedstock costs, further costs reduction are limited due to the continuing transportation constraint of physical (rather than weight) limits.

Sensitivity Scenario 6G: Increase HES Semi Trailer Capacity by 20 percent

In this scenario, HES semi trailer capacity is increased by 20 percent. This scenario evaluates the potential cost implications of identifying and using a (yet-to-be-identified) machine that crimps or squeezes the HES biomass feedstock (following its harvest and its being hauled to the edge of the field by buggies) prior to it being loaded onto the transport trucks, thereby reducing the moisture content and increasing the density of the biomass feedstock (which, in effect, increases the capacities of the transport trailers). Tables E114, E115, E116, and E117 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $51.85 million, i.e., $1.7284 per gallon of fuel produced, $699.22 per harvested acre of HES and SG, and $129.63 per dry ton of the requisite 400,000 tons of biomass feedstock (table E114). Under this scenario, total annual supply costs are reduced by $1.75 million, i.e., by $0.0583 per gallon of fuel produced, by $24.45 per harvested acre, and by $4.38 per dry ton (table E114).

A total of 314,801 dry tons of HES is produced on 36,678 acres while a total of 100,000 dry tons of SG is produced on 37,480 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 414,801 dry tons on 774,158 acres. For this sensitivity scenario, average HES and SG yields equate to 8.58 dry tons per acre and 2.67 dry tons per acre, respectively (table E114). Increasing HES semi trailer capacity reduces the impacts of trafficable days as more biomass feedstock can be transported during each respective period, thus allowing more HES biomass feedstock to be harvested during periods of higher-expected maximum HES yields. The required HES acreage is reduced by 167 acres, but SG acreage is increased by 255 acres as a result of the shifting of the relative timing of HES/SG harvest activities.

The total requisite initial investment for the CBFFE is estimated to be $113.48 million while the cost on an annual basis is estimated to be $14.17 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E115), resulting in an annual cost decrease of $749 thousand (table E114). Increasing HES transportation capacity reduces the number of semi trucks and HES trailer by 14 units, totaling a cost reduction of $323 thousand. The reductions in the numbers of semi truck and trailer units purchased are a direct result of increasing the carrying capacity of individual semi trailers. Although an increase in the number of wet tons produced would suggest an increase in the required number of semi truck and trailer units purchased, the increased capacity on each HES trailer offsets this increase.

The increase in HES wet ton production results from more acreage being harvested during the early harvest periods, thus increasing the amount of biomass feedstock that is transferred from period to period and subsequently increasing the amount of biomass feedstock deterioration and reducing the overall quantity of the biomass feedstocks in storage. This results in more biomass feedstock needing to be harvested to meet periodic requirements of the conversion facility. Excluding the decrease in semi trucks and HES trailer, machinery and equipment purchases are reduced by 13 units, resulting in annual cost savings of $300 thousand. This reduction in machinery does not result from a large reduction in acreage, but rather from the acreage operations being spread out more evenly across periods. For example, the spreading out of HES planting dates more evenly distributes the need for irrigation capacity, reducing the numbers of irrigation wells and re-lift pumps purchased by 5 wells and 1 pump, totaling annual capital costs savings of $107 thousand and $2 thousand, respectively.

Total annual operating costs are estimated to be $37.68 million (table E116), representing a $1 million decrease on an annual basis from the Year 2 Baseline Scenario (table E114). The most notable reduction is regards to the number of full-time employees hired. As noted earlier, full-time labor constitutes a large portion of annual operating costs with the majority of the laborers used for transportation. The decrease in HES end-dump semi trailers reduces the number of full-time employees required by 10 laborers, representing a reduction in annual operating costs of $489 thousand. The increase in HES trailer capacity also has a substantial impact on the costs to transport the HES biomass feedstock. HES transportation costs are reduced by $225 thousand.

Although slight, the reduction in HES acreage reduces the costs of performing HES field operations by $90 thousand. The most notable reduction in the costs of performing HES field operations is with regards to the costs of fertilizing, which is reduced by $63 thousand. The increase in SG acreage increase the costs of performing SG field operations by $19 thousand. The increase in SG acreage is directly correlated to the reduction in SG yields, occurring as a result of SG production shifting to periods with reduced yields when HES production was more-evenly distributed across periods (particularly favoring periods with higher yields). The slight reduction in SG yields is caused by more SG being harvested during periods of lower expected-maximum yield. To minimize costs and avoid the purchase of an additional semi-truck, the model moved some SG acreage to a lower maximum yield period which in turn reduced average yield.

Table E117 is a summary for Scenario 6G of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that increasing the physical capacity of the HES transportation trailers allows more biomass feedstock to be harvested and transported to the conversion facility each period, favoring periods with higher yields and resulting in a decrease in delivered biomass feedstock costs of $4.38 per dry ton.

Sensitivity Scenario 7A: 10 Dry Ton HES Yields With No Irrigation, Capital Costs Are Reduced by 15 Percent, and Trafficable Days are Set at 50 Percent

In this scenario, a portfolio of changes to the Year 2 Baseline Scenario assumptions are evaluated in an attempt to gauge the effects of simultaneous adjustments in several factors of apparent importance. Decreasing the maximum-expected HES harvested yield to 10 dry tons per acre and removing irrigation requirements, reducing capital costs by 15 percent, and setting trafficable days at the 50 percent probability level are the variables changed from the Year 2 Baseline Scenario. The pounds of fertilizer nutrients applied per acre are also decreased to recognize the decreased in the expected amount of biomass tonnage removed per acre. Tables E118, E119, E120, and E121 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $40.47 million, i.e., $1.3491 per gallon of fuel produced, $526.99 per harvested acre of HES and SG, and $101.18 per dry ton of the requisite 400,000 tons of biomass feedstock (table E118). Under this scenario, total annual supply costs are reduced by $13.13 million, i.e., by $0.4376 per gallon of fuel produced, by $196.68 per harvested acre, and by $32.83 per dry ton (table E118).

A total of 311,926 dry tons of HES is produced on 40,199 acres while a total of 100,000 dry tons of SG is produced on 36,601 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 411,926 dry tons on 76,800 acres. For this sensitivity scenario, average HES and SG yields equate to 7.76 dry tons per acre and 2.73 dry tons per acre, respectively (table E118). As expected, HES average harvested yields are decreased (by 0.75 dry tons per acre), resulting in an increase in required HES acreage of 3,354 acres. Average SG yields are increased by 0.04 dry tons per acre, resulting in a decrease in required SG acreage of 624 acres.

The total requisite initial investment for the CBFFE is estimated to be \$66.29 million while the cost on an annual basis is estimated to be \$8.64 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E119), resulting in an annual cost decrease of \$6.28 million (table E118). Increasing the number of trafficable days available and reducing the capital purchases cost have a direct impact on the costs and numbers of machinery and equipment purchased. Although an increase in HES acreage would suggest an increase in the required number of machinery and equipment purchases, the increase in the number of trafficable days counteracts this effect and effectively reduces the numbers of items purchased by 170 units, totaling an annual savings of \$3.34 million. The most notable reductions are in the costs of purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The number of semi trucks and HES end-dump semi trailers required is reduced by 38 units, totaling an annual capital costs savings of \$1.41 million. The numbers of HES harvesters, tractors size 2 (225 hp) and tractors size 1 (152 hp) required are reduced by 4 harvesters, 8 tractors, and 9 tractors, respectively, totaling annual cost reductions of \$488 thousand, $329 thousand, and $285 thousand, respectively. Reducing HES irrigation requirements to zero reduces the number of HES irrigation wells and re-lift pumps by 78 wells and 246 pumps, totaling cost savings of $1.66 million and $405 thousand, respectively.

Total annual operating costs are estimated to be $31.84 million (table E120), representing a $6.85 million decrease on an annual basis from the Year 2 Baseline Scenario (table E118). The most notable reduction is in regards to the number of full-time employees hired. The increase in the number of trafficable days and the subsequent reduction in the number of semi trucks and HES end-dump semi trailers reduce the required number of full-time employees hired by 50 laborers, constituting a reduction in annual operating costs of $2.47 million. Producing HES dryland (i.e., requiring no irrigation) eliminates 614,199 acre-inches of irrigation water applied and $3.44 million of pumping groundwater costs.

Due to the reduction in HES maximum-expected yields, the amount of HES acreage is increased by 3,354 acres, constituting an annual cost increase of $193 thousand. The increase in HES acreage increases the costs of performing all HES field operations except fertilizing by $355 thousand. Although increased acreage would suggest an increase in the costs of fertilizing, the reduction in HES yields and the explicit reduction in the amount of fertilizer nutrients applied per acre (occurring because less biomass is expected to be removed per acre) reduces the per acre costs of the fertilizing operation[161]. A total of 8.04 million pounds of nitrogen, 2.68 million pounds of phosphorus, and 5.36 million pound of potassium are required, summing to 16.08 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $626 thousand. However, a portion of this saving is eroded due to the increase in HES acreage and the subsequent increase in the costs of performing the fertilizing operation. The costs of performing the fertilizing operation is increased by $8 thousand due to increased acreage, resulting in the net decrease of $618 thousand.

Table E121 is a summary for Scenario 7A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that the assumed ultra-conservative HES harvest yield of non-irrigated 10 dry tons per acre and the pseudo-optimistic relaxed constraints regarding capital costs and trafficable days contribute to reductions in total-delivered biomass feedstock costs of $32.83 per dry ton. The reduction in costs is mainly attributed to the elimination of irrigation capital investment and operating costs and the

[161] Under the Year 2 Baseline Scenario, a total of 240 pounds of nitrogen, 80 pounds of phosphorus, and 160 pounds of potassium are required per acre. Under this scenario, a total of 200 pounds of nitrogen, 66.67 pounds of phosphorus, and 133.33 pounds of potassium are required. It is assumed that 20 pounds of nitrogen is required per tons of biomass removed and that the ratio is 3N-1P-2K (Blumenthal 2010).

increase in the number of trafficable days and the related effect on required capital investments and full-time labor requirements.

Sensitivity Scenario 7B: 12 Dry Ton HES Yields With Irrigation, Capital Costs Reduced 15 Percent, And Trafficable Days are Set at 50 Percent

This scenario is a continuation of the theme and rationale of scenario 7A, with several parameters marginally adjusted to represent a slightly more optimistic outlook for biomass feedstock production in the target area. In this scenario, the maximum-expected HES harvested yield is set to 12 dry tons per acre with irrigation (i.e.,same as in the Year 2 Baseline Scenario) while capital costs are reduced by 15 percent and trafficable days are set at the 50 percent probability level (i.e., these latter two variables are set at the same levels as in scenario 7A). Tables E122, E123, E124, and E125 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is \$43.91 million, i.e., \$1.4638 per gallon of fuel produced, \$636.29 per harvested acre of HES and SG, and \$109.79 per dry ton of the requisite 400,000 tons of biomass feedstock (table E122). Under this scenario, total annual supply costs are reduced by \$9.69 million, i.e., by \$0.3229 per gallon of fuel produced, by \$87.38 per harvested acre, and by \$24.22 per dry ton (table E122).

A total of 313,377 dry tons of HES is produced on 33,425 acres while a total of 100,000 dry tons of SG is produced on 35,591 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,377 dry tons on 69,016 acres. For this sensitivity scenario, average HES

and SG yields equate to 9.38 dry tons per acre and 2.81 dry tons per acre, respectively (table E122). Increasing the number of trafficable days provides more working hours per period and allows more acreage to be harvested during periods of higher-expected maximum HES and SG yields, thus increasing HES and SG yields and reducing the required acreage for both biomass feedstocks.

The total requisite initial investment for the CBFFE is estimated to be $84.68 million while the cost on an annual basis is estimated to be $10.11 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E123), resulting in an annual cost decrease of $4.81 million (table E122). Increasing the number of trafficable days available and reducing the capital purchase costs have a direct impact on the costs and numbers of machinery and equipment purchased. The increase in the number of trafficable days reduces the required number of HES and SG machinery and equipment purchases by 175 units, totaling an annual savings of $3.40 million. The most notable reductions in terms of costs are in regards to the costs of purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The number of semi trucks and HES end-dump semi trailers required is reduced by 36 units, totaling an annual capital costs savings of $1.10 million. The numbers of HES harvesters, tractors size 2 (225 hp) and tractors size 1 (152 hp) required are reduced by 4 harvesters, 9 tractors, and 8 tractors, respectively, totaling annual cost reductions of $488 thousand, $285 thousand, and $329 thousand, respectively. The decrease in HES acreage reduces the number of HES irrigation wells and re-lift pumps by 14 wells and 23 pumps, totaling cost savings of $503 thousand and $93 thousand, respectively. The numbers of storage units, storage land, and silo coverings required are increased by 12 units, 491,520 square-feet, and 285,120 square-feet, respectively, totaling annual cost increases of $317 thousand, $15 thousand, and $19 thousand, respectively.

Total annual operating costs are estimated to be $33.80 million (table E124), representing a $4.88 million decrease on an annual basis from the Year 2 Baseline Scenario (table E122). The most notable reduction is with regards to the number of full-time employees hired. The increase in the number of trafficable days and the subsequent reduction in the number of semi trucks and HES end-dump semi trailers reduce the required number of full-time employees hired by 50 laborers, constituting a reduction in annual operating costs of $2.47 million.

Due to the increase in HES and SG average yields, the amounts of HES and SG acreage leased are decreased by 3,420 acres and 1,634 acres, representing annual cost decreases of $197 thousand and $37 thousand, respectively. The decrease in HES acreage reduces the costs of performing HES and SG field operations by $1.02 million and $120 thousand. The most notable reduction in the costs of performing HES field operations involves the costs of fertilizing. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, decreases by $648 thousand. A total of 8.02 million pounds of nitrogen, 2.67 million pounds of phosphorus, and 5.35 million pound of potassium are required, summing to 16.04 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $640 thousand. Due to the decreased acreage, the amount of irrigation water applied is reduced by 57,009 acre-inches, totaling an annual cost decrease of $319 thousand.

Table E125 is a summary for Scenario 7B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that pseudo-optimistic assumptions of continued harvested HES yields of 12 dry tons per acre and relaxed constraints regarding capital costs and trafficable days contribute to reductions of total-delivered biomass feedstock costs by $24.72 per dry ton. The reduction in costs is mainly attributed to the increase in the number of trafficable days and the related effect on required capital investments and full-time labor requirements. The apparent superior performance (i.e., greater cost reductions) observed for scenario 7A relative to 7B are suggestive that the value of the expected two dry ton advantage of scenario 7B is insufficient to compensate for the requisite irrigation capital investment and operating costs.

Sensitivity Scenario 7C: 18 Dry Ton HES Yields With Irrigation, Capital Costs Reduced 15 Percent, and Trafficable Days are Set at 50 Percent

Continuing the logic of scenarios 7A and 7B, an even-more optimistic portfolio of adjustments to the Year 2 Baseline Scenario assumptions are investigated in scenario 7C. In this scenario, the maximum-expected HES harvested yield is increased to 18 dry tons per acre (with irrigation), capital costs are reduced by 15 percent, and trafficable days are set at the 50 percent probability level. Tables E126, E127, E128, and E129 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $39.43 million, i.e., $1.3143 per gallon of fuel produced, $669.32 per harvested acre of HES and SG, and $98.57 per dry ton of the requisite 400,000 tons of biomass feedstock (table E126). Under this scenario, total annual supply costs are reduced by $14.17 million, i.e., by $0.4724 per gallon of fuel produced, by $54.35 per harvested acre, and by $35.44 per dry ton (table E126).

A total of 311,746 dry tons of HES is produced on 22,383 acres while a total of 100,000 dry tons of SG is produced on 36,525 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 411,746 dry tons on 58,908 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 13.93 dry tons per acre and 2.74 dry tons per acre, respectively (table E126). Increasing maximum-expected HES yield to 18 dry tons per acre directly increases HES average-harvested yields. This increase in HES average-harvested yield is also caused by increasing the number of trafficable days which provides more working hours per period and allows more acreage to be harvested during periods of higher-expected maximum HES and SG yields, thus increasing HES and SG yields and reducing the required acreage for both biomass feedstocks.

The total requisite initial investment for the CBFFE is estimated to be \$78.05 million while the cost on an annual basis is estimated to be \$9.10 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E127), resulting in an annual cost decrease of \$5.82 million (table E126). The increase in HES maximum-expected harvested yield, the number of trafficable days available, and the reduction in the capital purchase costs have a direct impact on the costs and numbers of machinery and equipment purchased. The increase in the number of trafficable days and the increase in HES maximum-expected yield reduce the required number of HES and SG machinery and equipment purchases by 214 units, totaling annual savings of \$4.03 million. The most notable reductions in terms of costs are in regard to the costs of purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The numbers of semi trucks and HES end-dump semi trailers required are reduced by 40 units, totaling annual capital cost savings of \$1.18 million. The numbers of HES harvesters, tractors size 1 (225 hp) and tractors size 2 (152 hp) required are reduced by 7 harvesters, 14 tractors, and 10 tractors, respectively, totaling annual cost reductions of \$720 thousand, \$497 thousand, and \$303 thousand, respectively. A portion of the reduction in machinery and equipment purchased can be attributed to the reduction in HES and SG acreage. The decrease in HES acreage reduces the number of HES irrigation wells and re-lift pumps by 18 wells and 96 pumps, totaling costs savings of \$576 thousand and \$195 thousand, respectively.

Total annual operating costs are estimated to be \$30.33 million (table E128), representing an annual \$8.35 million decrease from the Year 2 Baseline Scenario (table E126). The most notable reduction is in the number of full-time employees hired. The increase in the number of trafficable days and the reduction in HES acreage reduce the required number of full-time employees hired by 60 laborers, representing a reduction in annual operating costs of \$2.94 million. The additional reduction of 10 laborers in 7C (reduction of 60 versus the reductions of 50 in scenarios 7A and 7B) are attributable to the higher yields of scenario 7C reducing the requisite HES acreage and associated field operations.

Due to the increase in HES and SG average yields, the amounts of HES and SG acreage leased are decreased by 14,462 acres and 700 acres, constituting annual cost decreases of \$832 thousand and \$16 thousand, respectively. The decrease in HES acreage reduces the costs of performing HES and SG field operations by \$2.20 million and \$51 thousand. The most notable reductions in the costs of performing HES field operations are with respect to the costs for fertilizing, planting, and harvesting. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by \$647 thousand. A total of 8.06 million pounds of nitrogen, 2.69 million pounds of phosphorus, and 5.37 million pound of potassium are required, summing to 16.12 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $406 thousand. The costs of the planting operation and the costs of the harvesting operation are decreased by $577 thousand and $465 thousand, respectively, due to the decrease in HES acreage. As a result of the decreased HES acreage, the amount of irrigation water required is reduced by 241,079 acre-inches, totaling an annual cost decrease of $1.35 million.

Table E129 is a summary for Scenario 7C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that pseudo-optimistic developments in HES harvest yields of 18 dry tons per acre and relaxed constraints regarding capital costs and trafficable days reduce total-delivered biomass feedstock costs by $35.44 per dry ton. The reduction in costs is mainly attributed to the increase in HES yields and the number of trafficable days and the subsequent affect on required capital investments and full-time labor requirements. The assumed increase of 6 dry tons in HES maximum-expected harvested HES yields appears to provide for substantial reductions in per dry ton biomass feedstock delivered costs, at the frontgate of the conversion facility.

Sensitivity Scenario 8A: 10 Dry Ton HES Yields With No Irrigation, Both Capital and Operating Costs Reduced 15 percent, Trafficable Days are Set at 50 percent, and Transportation Capacity Is Increased 20 percent

The portfolio of adjustments embedded in the scenario 8A assumptions represent a degree of optimism surpassing that expressed in scenario 7A. In this scenario, (1) decreasing the maximum-expected HES harvested yield to 10 dry tons per acre and removing irrigation requirements, (2) reducing capital and operating costs by 15 percent, (3) setting trafficable days at the 50 percent probability level, and (4) increasing HES semi trailer capacity by 20 percent are the variables changed from the Year 2 Baseline Scenario. The pounds of fertilizer nutrients applied per acre also are decreased to recognize the decrease in the expected amount of biomass tonnage removed per acre. Tables E130, E131, E132, and E133 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $34.73 million, i.e., $1.1576 per gallon of fuel produced, $455.21 per harvested acre of HES and SG, and $86.82 per dry ton of the requisite 400,000 tons of biomass feedstock (table E130). Under this scenario, total annual supply costs are reduced by $18.87 million, i.e., by $0.6291 per gallon of fuel produced, by $268.46 per harvested acre, and by $47.19 per dry ton (table E130).

A total of 312,275 dry tons of HES is produced on 39,806 acres while a total of 100,000 dry tons of SG is produced on 36,485 acres to meet the annual biomass

feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 412,275 dry tons on 76,291 acres. For this sensitivity scenario, average HES and SG yields equate to 7.84 dry tons per acre and 2.74 dry tons per acre, respectively (table E130). As expected, HES average yields are decreased by 0.66 dry tons per acre, resulting in an increase in required HES acreage of 2,961 acres. Average harvested SG yields are increased by 0.05 dry tons per acre, resulting in a decrease in required SG acreage of 740 acres.

The total requisite initial investment for the CBFFE is estimated to be $64.67 million while the cost on an annual basis is estimated to be $8.36 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E131), resulting in an annual cost decrease of $6.56 million (table E130). Increasing the number of trafficable days available and reducing the capital purchase costs have a direct impact on the costs and numbers of machinery and equipment purchased. Although an increase in HES acreage would suggest an increase in the required number of machinery and equipment purchases, the increase in the number of trafficable days counteracts this effect and reduces the numbers of items purchased by 195 units, totaling a savings of $3.62 million. The most notable reductions in terms of costs are in the costs of purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The numbers of semi trucks and HES end-dump semi trailers required are reduced by 49 units, totaling an annual capital cost savings of $1.36 million. A portion of the decrease in the number of semi truck and trailer units required is due to the increase in HES semi trailer capacity. The numbers of HES harvesters, tractors size 2 (225 hp) and tractors size 1 (152 hp) required are reduced by 5 harvesters, 7 tractors, and 9 tractors, respectively, totaling annual cost reductions of $565 thousand, $301 thousand, and $285 thousand, respectively. Reducing HES irrigation requirements to zero reduces the number of HES irrigation wells and re-lift pumps by 78 wells and 246 pumps, totaling costs savings of $1.66 million and $405 thousand, respectively.

Total annual operating costs are estimated to be $26.37 million (table E132), representing an annual $12.31 million decrease from the Year 2 Baseline Scenario (table E130). The most notable reduction is in the number of full-time employees hired. The increase in the number of trafficable days and the increase in HES semi trailer capacity reduce the number of semi trucks and HES end-dump semi trailers required, and, thus, reduce the required number of full-time employees hired by 60 laborers, representing a reduction in annual operating costs of $3.74 million. The additional reduction of 10 laborers in this scenario beyond the 50 laborer reduction identified in scenario 7A is associated with the added transportation capacity of 20 percent and ensuing lessening of transport truck drivers.

Producing HES without irrigation reduces the acre-inches of applied irrigation water by 614,199 and decreases the costs of pumping groundwater by $3.44 million. Due to the reduction in HES maximum-expected yields, the amount of HES acreage is increased by 2,961 acres, representing an annual cost increase of $173 thousand. Although increased acreage would suggest an increase in the costs of fertilizing, reducing operating costs by 15 percent and the reduction in expected HES yields and the explicit reduction in the amount of fertilizer nutrients applied per acre (occurring because less biomass is expected to be removed per acre) reduce the cost of the fertilizing operation[162]. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by $1.63 million. A total of 7.96 million pounds of nitrogen, 2.65 million pounds of phosphorus, and 5.31 million pound of potassium are required, summing to 15.92 million pounds annually. This reduction in amount of fertilizer nutrients required reduces the costs of purchasing fertilizer nutrients by $688 thousand.

The remainder of the costs savings is attributed to the 15 percent reduction in operating costs. The reduction in operating costs also has a significant impacts on the costs of performing HES field operations and the costs of transporting HES. The cost of performing HES field operations is reduced by $555 thousand while the costs of transporting HES are reduced by $543 thousand.

Table E133 is a summary for Scenario 8A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that for the assumed ultra-conservative HES

[162] Under the Year 2 Baseline Scenario, a total of 240 pounds of nitrogen, 80 pounds of phosphorus, and 160 pounds of potassium are required per acre. Under this scenario, a total of 200 pounds of nitrogen, 66.67 pounds of phosphorus, and 133.33 pounds of potassium are required per acre. It is assumed that 20 pounds of nitrogen is required per tons of biomass removed and that the ratio is 3N-1P-2K. (Blumenthal 2010).

harvested yield of 10 dry tons per acre and optimistic relaxed constraints regarding capital and operating costs, trafficable days, and transportation capacity, total-delivered biomass feedstock costs are reduced by $47.19 per dry ton. The reduction in costs is mainly attributed to the elimination of irrigation capital investment and operating costs and the increase in the number of trafficable days and the related effect on required capital investments and full-time labor requirements. The increase in HES transport trailer capacity and reduction in both capital and operating costs further reduced biomass feedstock costs.

Sensitivity Scenario 8B: 12 Dry Ton HES Yields With Irrigation, Both Capital and Operating Costs Reduced 15 percent, Trafficable Days are Set at 50 percent, and Transportation Capacity Increased 20 percent

The harvested HES yield expectations are the same as for the Year 2 Baseline Scenario (i.e., slightly higher here than for scenario 8A, but irrigation is required). In this scenario, (1) maximum-expected HES harvested yield is set to 12 dry tons per acre, (2) capital and operating costs are reduced by 15 percent, (3) trafficable days are set at the 50 percent probability level, and (4) HES semi trailer capacity is increased by 20 percent. Items (2), (3), and (4) are the variables changed from the Year 2 Baseline Scenario. The pounds of fertilizer nutrients applied per acre remain the same as for the Year 2 Baseline Scenario as the expected amount of biomass tonnage removed per acre is the same. Tables E134, E135, E136, and E137 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is \$37.82 million, i.e., \$1.2608 per gallon of fuel produced, \$549.05 per harvested acre of HES and SG, and \$94.56 per dry ton of the requisite 400,000 tons of biomass feedstock (table E134). Under this scenario, total annual supply costs are reduced by \$15.78 million, i.e., by \$0.5259 per gallon of fuel produced, by \$174.62 per harvested acre, and by \$39.45 per dry ton (table E134).

A total of 314,032 dry tons of HES is produced on 33,134 acres while a total of 100,000 dry tons of SG is produced on 35,756 acres to meet the annual biomass

feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 414,032 dry tons on 68,890 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 9.48 dry tons per acre and 2.88 dry tons per acre, respectively (table E134). The increase in the number of trafficable days provides more working hours per period and allows more acreage to be harvested during periods of higher-expected maximum HES and SG yields while the increase in HES semi trailer capacity allows each truck to carry more biomass feedstock, thus reducing the dependance on semi truck and trailer units during periods of intensified harvest. These two factors allow for more acreage to be harvested during periods of higher-expected maximum HES yields and reduces the required acreage for both biomass feedstocks.

The total requisite initial investment for the CBFFE is estimated to be $82.80 million while the cost on an annual basis is estimated to be $9.77 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E135), resulting in an annual cost decrease of $5.15 million (table E134). The increase in HES maximum-expected yields and the number of trafficable days available and the reduction in the capital purchase costs have a direct impact on the costs and numbers of machinery and equipment purchased. The total numbers of HES and SG machinery and equipment purchased are decreased by 201 units, totaling annual savings of $3.76 million. The most notable reductions in terms of cost are in regards to purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The numbers of semi trucks and HES end-dump semi trailers required are reduced by 47 units, totaling an annual capital cost savings of $1.32 million. A portion of the decrease in the number of semi truck and trailer units required is due to the increase in HES semi trailer capacity. The numbers of HES harvesters, tractors size 2 (225 hp) and tractors size 1 (152 hp) required are reduced by 5 harvesters, 9 tractors, and 9 tractors, respectively, totaling annual cost reductions of $565 thousand, $357 thousand, and $285 thousand, respectively. The decrease in HES acreage reduces the number of HES irrigation wells and re-lift pumps by 14 wells and 25 pumps, totaling a costs savings of $503 thousand and $96 thousand, respectively.

Total annual operating costs are estimated to be $28.06 million (table E136), representing a $10.63 million decrease on an annual basis from the Year 2 Baseline Scenario (table E134). The most notable reduction is in the number of full-time employees hired. The increase in the number of trafficable days and the increase in HES semi trailer capacity reduce the number of semi trucks and HES end-dump semi trailers required and, thus, reduces the required number of full-time employees hired. The number of full-time employees hired is reduced by 60 laborers, producing a reduction in annual operating costs of $3.74 million. The additional reduction of 10 laborers in this scenario beyond the 50 laborer reduction identified in scenario 7B is associated with the added transportation capacity of 20 percent and ensuing lessening of transport truck drivers.

Due to the increase in HES average-harvested yields, the amount of HES acreage is decreased by 3,711 acres, representing an annual costs decrease of $499 thousand. The decrease in HES acreage and the reduction in operating costs reduce the costs of performing HES and SG field operations by $2.55 million and $601 thousand, respectively. The most notable reductions in the costs of performing HES field operations are in the costs of fertilizing, planting, and harvesting. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by $1.65 million. A total of 7.95 million pounds of nitrogen, 2.65 million pounds of phosphorus, and 5.30 million pounds of potassium are required, summing to 15.90 million pounds annually. This reduction in amount of fertilizer nutrients required (due to reduced HES acreage) reduces the costs of purchasing fertilizer nutrients by $695 thousand.

The remainder of the costs savings is attributed to the 15 percent reduction in operating costs. The costs of the planting operation and the costs of the harvesting operation are reduced by $346 thousand and $249 thousand, respectively. The amount of irrigation water required is reduced by 61,870 acre-inches, totaling an annual cost decrease of $797 thousand. The reduction in operating costs and the increase in HES semi trailer capacity reduces the costs of HES transportation by $546 thousand. A portion of the decrease in HES transportation costs is attributed to the more tonnage being transported per load, reducing the number of loads.

Table E137 is a summary for Scenario 8B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that the assumption of continued harvested HES yields of 12 dry tons per acre and optimistic relaxed constraints regarding capital and operating costs, trafficable days, and transportation capacity contribute to reduced total-delivered biomass feedstock costs of $39.45 per dry ton. The reduction in costs is mainly attributed to the increase in the number of trafficable days and the related effect on required capital investments and full-time labor requirements. The apparent superior performance (i.e., greater cost reductions) observed for scenario 8A relative to 8B are suggestive that the value of the expected two dry ton advantage of scenario 8B is insufficient to compensate for the requisite irrigation capital investment and operating costs. The increase in HES transport trailer capacity and reduction in both capital and operating costs further reduced biomass feedstock costs.

Sensitivity Scenario 8C: 18 Dry Ton HES Yields With Irrigation, Both Capital and Operating Costs Reduced 15 percent, Trafficable Days Set at 50 percent, and Transportation Capacity Increased 20 percent

This sensitivity scenario represents the most optimistic portfolio of changes to Year 2 Baseline Scenario assumption. In this scenario, (1) the maximum-expected HES harvested yield is increased to 18 dry tons per acre (with irrigation), (2) capital and operating costs are reduced by 15 percent, (3) trafficable days are set at the 50 percent probability level, and (4) HES semi trailer capacity is increased by 20 percent. The pounds of fertilizer nutrients applied per acre are increased to recognize the increase in the expected amount of biomass tonnage removed per acre. Tables E138, E139, E140, and E141 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast, Edna-Ganado, Texas area under this scenario is $33.90 million, i.e., $1.1300 per gallon of fuel produced, $570.25 per harvested acre of HES and SG, and $84.75 per dry ton of the requisite 400,000 tons of biomass feedstock (table E138). Under this scenario, total annual supply costs are reduced by $19.70 million, i.e., by $0.6567 per gallon of fuel produced, by $153.42 per harvested acre, and by $49.26 per dry ton (table E138).

A total of 313,282 dry tons of HES is produced on 22,631 acres while a total of 100,000 dry tons of SG is produced on 36,815 acres to meet the annual biomass feedstock needs of the conversion facility. Thus, the total amount of biomass feedstock produced is 413,282 dry tons on 59,446 acres. For this sensitivity scenario, average harvested HES and SG yields equate to 13.84 dry tons per acre and 2.72 dry tons per acre, respectively (table E138). As expected, harvested HES average yields are increased by 5.34 dry tons per acre, resulting in an decrease in required HES acreage of 14,214 acres. Average harvested SG yields are increased by 0.03 dry tons per acre, resulting in a decrease in required SG acreage of 410 acres.

The total requisite initial investment for the CBFFE is estimated to be $73.74 million while the cost on an annual basis is estimated to be $8.55 million (calculated on an annuity equivalent basis (including insurance, property taxes, and fixed repairs ownership costs)) (table E139), resulting in an annual cost decrease of $6.37 million (table E138). The increase in HES maximum-expected yields and the number of trafficable days available and the reduction in the capital purchase costs have a direct impact on the costs and numbers of machinery and equipment purchased. The total numbers of HES and SG machinery and equipment purchased are decreased by 243 units, totaling an annual savings of $4.40 million. The most notable reductions in terms of costs relate to purchasing semi trucks and HES end-dump semi trailers, HES harvesters, tractors size 1 (225 hp), and tractors size 2 (152 hp). The numbers of semi trucks and HES end-dump semi trailers required are reduced by 51 units, totaling annual capital cost savings of $1.40 million. The numbers of HES harvesters, tractors size 1 (225 hp) and tractors size 2 (152 hp) required are reduced by 7 harvesters, 14 tractors, and 9 tractors, respectively, totaling annual cost reductions of $720 thousand, $497 thousand, and $285 thousand, respectively. A portion of the reduction in machinery and equipment purchased can be attributed to the reduction in HES and SG acreage. The decrease in

HES acreage reduces the number of HES irrigation wells and re-lift pumps by 30 wells and 95 pumps, totaling cost savings of $793 thousand and $194 thousand, respectively.

Total annual operating costs are estimated to be $25.35 million (table E140), representing a $13.34 million decrease on an annual basis from the Year 2 Baseline Scenario (table E138). The most notable reduction is in the number of full-time employees hired. The increase in the number of trafficable days and HES maximum-expected yield and the increase in HES semi trailer capacity reduce the number of semi trucks and HES end-dump semi trailers required and, thus, reduce the required number of full-time employees hired. The number of full-time employees hired is reduced by 70 laborers, representing a reduction in annual operating costs of $4.16 million**.** The additional reduction of 10 laborers in 8C (reduction of 70 versus the reductions of 60 in scenarios 8A and 8B) are attributable to the higher yields of scenario 8C reducing the requisite HES acreage and associated field operations.

Due to the increase in HES maximum-expected yields, the amount of HES acreage is decreased by 14,214 acres, constituting an annual cost decrease of $1.01 million. The decrease in HES acreage and the reduction in operating costs reduce the costs of performing HES and SG field operations by $3.41 million and $535 thousand, respectively. The most notable reductions in the costs of performing HES field operations are in the costs of fertilizing, planting, and harvesting. The annual costs of fertilizing, including the costs of performing the operation and the cost of the fertilizer nutrients, are decreased by $1.54 million. A total of 8.15 million pounds of nitrogen, 2.72 million pounds of phosphorus, and 5.43 million pound of potassium are required, summing to 16.29 million pounds annually. This reduction in amount of fertilizer nutrients required (due to the effects of reducing HES acreage out weighing the effects of an increase in the amount of fertilizer nutrients applied per acre due to increased maximum-expected HES yields) reduces the costs of purchasing fertilizer nutrients by $543 thousand.

The remainder of the costs savings is attributed to the 15 percent reduction in operating costs. The costs of the planting operation and the costs of the harvesting operation are decreased by $702 thousand and $542 thousand, respectively. Due to the decreased acreage, the amount of irrigation water applied is reduced by 236,941 acre-inches, totaling an annual cost decrease of $1.63 million. The reduction in operating costs and the increase in HES semi trailer capacity reduce the costs of HES transportation by $553 thousand.

Table E141 is a summary for Scenario 8C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that optimistic developments in HES harvested yields of 18 dry tons per acre and relaxed constraints regarding capital and operating costs, trafficable days, and transportation capacity reduce total-delivered biomass feedstock costs by $49.26 per dry ton. The reduction in costs is mainly attributed to the increase in HES yields and the number of trafficable days and the subsequent affect on required capital investments and full-time labor requirements. The assumed increase of 6 dry tons in HES maximum-expected harvested HES yields appears to provide for substantial reductions in per dry ton biomass feedstock delivered costs, at the frontgate of the conversion facility.

Sensitivity Scenario 9A: Higher Returns on HES Rotation Acreage

In this scenario, the income from leasing HES land during the two years out of production is increased from $10 per acre to $110 per acre. This assumption reduces the annual costs of leasing one acre of HES land to -$42.50 per acre, i.e., an overall negative cost (an actual positive return to the CBFFE) for leasing HES acreage from landowners! It is assumed that HES is planted on what is now pasture land; however, once the land is "broken out" and converted to a cultivated state, it is assumed in this scenario that it is unlikely that during the two years out of HES production that the land will revert back to pasture (Harris 2011). For example, the land could potentially be leased at a higher rate to area producers to grow a legume-type crop. Changing the HES land lease cost is the only variable changed from the Year 2 Baseline Scenario. Tables E142, E143, E144, and E145 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast Edna-Ganado, Texas area under this scenario is $49.70 million, i.e., $1.6568 per gallon of fuel produced, $650.15 per harvested acre of HES and SG, and $124.26 per dry ton of the requisite 400,000 tons of biomass feedstock (table E142). Under this scenario, total annual supply costs are reduced by $3.90 million, i.e., $0.1299 per gallon of fuel produced, $73.52 per harvested acre, and $9.75 per dry ton (table E142). As expected, reducing HES land lease costs has the most significant impact on the costs of leasing HES land which is reduced to -$1.64 million on an annual basis (table E144); that is, the rented land is a net revenue-producing item.

Several of the Sorghasaurus© activity solutions are different than observed for the Year 2 Baseline Scenario. Capital investment costs declined because HES land is cheaper to lease relative to the cost of machinery, with 1,808 more acres of HES land being leased. As a result, machinery use was spread across more acres (i.e., more acres were harvested during non-peak HES maximum yields, evidenced by the lower HES yield 8.15 vs. 8.50) which lowered the amount of machinery that had to be purchased because there was excess trafficable days in those periods.

Assuming the approximate 80,000 acres of HES land not in production during the "two out" rotation years can be leased to area producers raises the question of "why are area producers not already utilizing this land in such a manner?" That is, the validity/ accuracy of the assumptions embodied in this scenario are suspect if one assumes that producers in the targeted study area are economically-rational decision agents. Certainly the absence of direct government payments on such acreage is most probably a deterrent to its being farmed during the rotation years. The restriction on the producers to only grow legume-type crops so as to not deplete the soil nutrients could also potentially hinder the demand for the acreage. The possibility and the extent to which leasing HES land would occur and at what price during the two years that it is not in production are deserving of further research.

Table E145 is a summary for Scenario 9A of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock

(Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that although it may appear economically and financially attractive to lease the acreage to area producers at such inflated sub-lease rates, the cropping restrictions that would be placed on the producers by the CBFFE (e.g., legume-type crops only), the anticipated absence of direct government payments on such acreage, and the fact that the land is not farmed currently raise serious questions of the validity of this assumption and the associated analytical results derived for this scenario.

Sensitivity Scenario 9B: Reduce Irrigation Operating Costs to Zero

In this scenario, irrigation operating costs are reduced to zero. There is some speculation that HES might not require supplemental irrigation during the immediate post-planting stages every year due to frequent sufficient rainfall in the Middle Gulf Coast region (Harris 2011; Rooney 2011). However, it is assumed that the CBFFE would still invest in the irrigation wells and canals for use during years which rainfall is not sufficient to ensure establishment of a quality HES stand. Reducing irrigation operating costs to zero is the only variable changed from the Year 2 Baseline Scenario. Tables E146, E147, E148, and E149 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast Edna-Ganado, Texas area under this scenario is $49.97 million, i.e., $1.6656 per gallon of fuel produced, $653.61 per harvested acre of HES and SG, and $124.92 per dry ton of the requisite 400,000 tons of biomass feedstock (table E146). Under this scenario, total annual supply costs are reduced by $3.63 million, i.e., $0.1211 per gallon of fuel produced, $70.06 per harvested acre, and $9.09 per dry ton (table E146). The majority of the costs savings is attributed to reducing the cost of pumping irrigation water which accounts for $3.44 million while the remainder of the reduction is on capital investments. Capital investments are reduced as a result of non-concern for the number of requisite irrigation wells (since they are not being used) which allows greater distribution of HES production operations across time periods, lessening the demand for capital machinery and equipment.

The financial and economic feasibility of the conversion facility relies heavily on a consistent annual supply of biomass feedstocks. Weather data provided by Raun (2010) are suggestive that average monthly rainfall in the study region is approximately 4 inches but that it ranges from 0 to 12.6 inches during the critical stand establishment periods of March - May (refer to figure D1). A subjective assessment of the historical rainfall data illustrated in figures D1 and D2 is indicative that, while on average irrigation may not be required, there exists the potential for minimal rainfall events, implying that necessarily some supplemental irrigation will be required to ensure quality biomass feedstock stands and associated harvested yields. The results of this scenario indicate that in any given year in which rainfall is sufficient, not irrigating (i.e., eliminating irrigation operating expenditures) could reduce biomass feedstock costs by $9.09 per dry ton. In the Year 2 Baseline Scenario of this research, however, irrigation is assumed to reduce risk, and investments in wells and canals are warranted as are the operating costs associated with pumping the applied irrigation water, with the noted $9.09 per dry ton representing an insurance premium.

Table E149 is a summary for Scenario 9B of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The ‘take aways’ from this scenario’s results and the interpretation provided above are that should sufficient rainfall occur during the immediate post-planting stages as to not require supplemental irrigation, total-delivered biomass feedstock costs would be reduced materially. Due to the perceived risk-averse nature of the CBFFE and subjective review of historical rainfall data suggesting there is the potential for minimal rainfall events, however, the Year 2 Baseline Scenario's assumption of investments in wells and canals are warranted as are the operating costs associated with pumping the applied irrigation water.

Sensitivity Scenario 9C: No SG Harvest During April and May

In this scenario, no SG is allowed to be harvested during the initial spring regrowth periods (i.e., April and May) (Rooney 2011). Harvesting SG during the initial spring regrowth periods could potentially reduce maximum-expected yields for the following years and would most likely reduce the expected useful life of the SG stand from 10 years to 6 years (Rooney 2011). Allowing no SG Harvest during the April and May periods is the only variable changed from the Year 2 Baseline Scenario. Tables E150, E151, E152, and E153 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast Edna-Ganado, Texas area under this scenario is $54.33 million, i.e., $1.8111 per gallon of fuel produced, $712.08 per harvested acre of HES and SG, and $135.83 per dry ton of the requisite 400,000 tons of biomass feedstock (table E150). Under this scenario, total annual supply costs are increased by $730 thousand, i.e., $0.0244 per gallon of fuel produced and $1.82 per dry ton (table E150).

The costs per acre decreases by $11.59 per acre due to more acreage being available to spread the capital ownership costs across, but costs per ton and per gallon increase as a result of lower harvested yields per acre. Unexpectedly, the majority of the costs increase is attributed to the increased dependance on HES as more HES biomass feedstock (and acres) are harvested to supplement the conversion facility's biomass feedstock requirements during the April and May periods rather than SG being harvested in other periods and stored until needed. Annual capital investment costs are increased by $92 thousand and annual operating costs are increased by $638 thousand. The two most significant operating costs increases are on the costs of fertilizing and irrigating HES which are increased by $204 thousand and $100 thousand, respectively.

Table E153 is a summary for Scenario 9C of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that the consequences of not allowing SG harvest during the initial spring regrowth has a relatively-small impact on the total annual costs. The consequences of limiting/avoiding SG harvest during certain months need to be quantified as the impacts on maximum-expected yields and stand longevity could potentially significantly impact costs. Results for this scenario, and the discussion associated with its inception, point toward it being an area deserving of future research attention in biomass feedstock supply research programs, particularly with respect to local geographic areas while also recognizing the availability or lack thereof of alternative biomass feedstock supply sources.

Sensitivity Scenario 9D: No Integer Programming for Year 2 Baseline Scenario

In this scenario, no integer programming constraints are placed on capital purchases of headquarters, land, machinery and equipment, full-time labor, irrigation wells, and storage facilities. Removing these integer programming features from the analysis permits the model to purchase a fraction of each capital investment or hire a fraction of an employee, thus reducing costs, i.e., not 'rounding up' all capital purchases to whole-unit increments. Tables E154, E155, E156, and E157 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a 30-million gallon conversion facility in the Middle Gulf Coast Edna-Ganado, Texas area under this scenario is $53.49 million, i.e., $1.7830 per gallon of fuel produced, $722.21 per harvested acre of HES and SG, and $133.73 per dry ton of the requisite 400,000 tons of biomass feedstock (table E154). Under this scenario, total annual supply costs are decreased by $112 thousand, i.e., $0.0037 per gallon of fuel produced, $1.46 per harvested acre, and $0.28 per dry ton (table E154).

As expected, the costs decrease is attributed to the reduction in the required number of capital investments as the model is permitted to purchase a fraction of each item instead of purchasing a whole piece of machinery or equipment. The majority of the costs saving is attributed to reducing the required number of irrigation wells from 78 wells to 71.6 wells totaling a costs savings of $129 thousand. This reduction is partially attributed to the decrease in the required amount of HES land although the majority of the reduction is due to more land being planted during periods of increased trafficable days and thus increased well pumping capacity. Removing the integer constraint features reduces the required numbers of machinery and equipment purchased by 5.5 pieces, totaling $15 thousand.

A somewhat unexpected result is that annual operating costs are increased by $40 thousand. Although there are reduction in certain operating costs, these reduction are offset by the $93 thousand increase in the costs to hire full-time employees. The number of full-time employees required increases due to the optimization process of the model and more biomass feedstock being harvest during periods of higher-expected-maximum yield which correspond to periods of low trafficability (table E157).

Table E157 is a summary for Scenario 9D of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The takeaway from the results for this scenario relative to the Year 2 Baseline Scenario is that by removing integer programming constraints on capital purchases, the total-delivered biomass feedstock costs are reduced, but not at a significant level. This reduction can be attributed to the many units of machinery and equipment that are purchased and the level of biomass feedstock production required by the CBFFE (i.e., 400,000 dry tons) which dilutes the numbers. For a smaller farm with less machinery and less production, the results would most likely be more pronounced[163]. However, the Year 2 Baseline Scenario's assumption of requiring such integer programming and not allowing fraction purchases of capital items provides a "real world" assessment of the costs of a business organization such as the assumed CBFFE to supply a conversion facility with alternative biomass feedstock.

[163] Such a perception is investigated in scenario 9A.

Sensitivity Scenario 9E: No Integer Programming on Economies of Size Scenario 6E

In this scenario, no integer programming constraints are imposed on 2,500-acre farm unit purchases of capital headquarters, land, machinery and equipment, full-time labor, irrigation wells, and storage facilities, in contrast to the assumptions used in the economies-of-size sensitivity scenario 6E. Removing the integer programming constraints permits the model to purchase a fraction of each capital investment or hire a fraction of an employee, thus reducing costs. This scenario is the structure noted at the end of the discussion of scenario 9D. Tables E158, E159, E160, and E161 include select details of the results for this sensitivity scenario, with some reference to corresponding results for the Year 2 Baseline Scenario.

The total annual cost to supply a farm size capable of annually producing 21,500 tons of HES in the Middle Gulf Coast Edna-Ganado, Texas, area under this scenario is $5.09 million, i.e., $3.1561 per gallon of fuel produced, $2,057.29 per harvested acre of HES and SG, and $236.71 per dry ton (table E158). A total of 18.6 farms are required to produce 30-million gallons of biofuels, thus the total annual costs as compared to the baseline year 2 scenario is $94.66 million. The total annual supply costs are increased by $41.06 million i.e., $1.3695 per gallon of fuel produced, $1,333.62 per harvested acre, and $102.70 per dry ton (table E158). As expected, the costs decrease is attributed to the reduction in the required number of capital investments as the model is permitted to purchase a fraction of each item instead of purchasing a whole piece of machinery or equipment.

Table E161 is a summary for Scenario 9E of the (1) total annual cost for the hypothetical corporate biomass feedstock farming entity; (2) cost per planted acre of biomass feedstock; (3) cost per dry ton of biomass feedstock; (4) cost per gallon of biofuels (assuming 75 gallons of biofuel produced per dry ton of biomass feedstock (Avant 2009)); and (5) proportion of total annual costs distributed between capital investment and annual operating costs. The 'take aways' from this scenario's results and the interpretation provided above are that by removing the integer programming constraints on capital purchases for a relatively-smaller size farm operation (than that of the CBFFE in the Year 2 Baseline Scenario), the absolute and relative reduction in the costs to supply a conversion facility with biomass feedstocks is more pronounced for the smaller-farm size with less machinery and less production. When compared to the sensitivity scenario 6E economies of size run in which integer programming was imposed on capital asset purchases, capital investment costs are reduced in scenario 9E by 15 percent and annual operating costs are reduced by 14 percent. That is, integer constraint requirements imposed on capital purchases in the real world have a greater proportional effect on smaller businesses versus larger ones.

Table E1. Identification of Appendix E Tables, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Scenario	Description of Scenario	Appendix E Table Numbers
Scenario 1A	Three Extra Periods of Biorefinery Biomass feedstock Requirements	E2-E5
Scenario 1B	Excess SG Production Equivalent to 25% of Biorefinery Biomass feedstock Requirements	E6-E9
Scenario 2A	HES Yield @ 8 tons/ac and no Irrigation	E10-E13
Scenario 2B	HES Yield @ 12 tons/ac and no Irrigation	E14-E17
Scenario 2C	HES Yield @ 18 tons/ac	E18-E21
Scenario 2D	HES Yield @ 25 tons/ac	E22-E25
Scenario 3A	SG @ 2 tons/ac	E26-E29
Scenario 3B	SG @ 6 tons/ac	E30-E33
Scenario 4A	Only HES for Principal Supply, Plus 25% SG for Insurance	E34-E37
Scenario 4B	Only SG for Principal Supply, Plus 25% SG for Insurance	E38-E41
Scenario 5A	Capital Costs are Reduced 15%	E42-E45
Scenario 5B	Capital Costs are Increased 15%	E46-E49
Scenario 5C	Operating Costs are Reduced 15%	E50-E53
Scenario 5D	Operating Costs are Increased 15%	E54-E57
Scenario 5E	Discount Rate is Reduced 1%	E58-E61
Scenario 5F	Consider Only Farm Gate Costs	E62-E65
Scenario 5G	Consider Only Just-In-Time Deliveries	E66-E69
Scenario 5H	Just-in-Time Deliveries with Adjusted Trafficable Days	E70-E73
Scenario 5I	No Full-Time Labor (only part-time)	E74-E77
Scenario 5J	Lease all Transportation (versus purchased)	E78-E81
Scenario 5K	Periodic Storage Deterioration Increased to 5.0%	E82-E85
Scenario 5L	Periodic Storage Deterioration Decreased to 0.2%	E86-E89

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Table E1, continued.

Scenario	Description of Scenario	Appendix E Table Numbers
Scenario 6A	Trafficable Days at 50%	E90-E93
Scenario 6B	Trafficable Days at 90%	E94-E97
Scenario 6C	Only SG Grown with Trafficable Days at 90%	E98-E101
Scenario 6D	Trafficable Days Relaxed (x10)	E102-E105
Scenario 6E	Economics of Farm Size, with no SG and no Insurance	E106-E109
Scenario 6F	Maximum HES Harvest Moisture set at 25%	E110-E113
Scenario 6G	Increase Transportation Capacity 20%	E114-E117
Scenario 7A	10 Dry Ton HES Yields with no Irrigation	E118-E121
Scenario 7B	12 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15% using only Part-Time Labor, and Trafficable Days at 50%	E122-E125
Scenario 7C	18 Dry Ton HES Yields with Irrigation, Capital Costs Reduced 15% using only Part-Time Labor, and Trafficable Days at 50%	E126-E129
Scenario 8A	10 Dry Ton HES Yields with no Irrigation, both Capital and Operating Costs Reduced 15% using Part-Time Labor, Trafficable Days at 50%, and Transportation Capacity Increased 20%	E130-E133
Scenario 8B	12 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15% using Part-Time Labor, Trafficable Days at 50%, and Transportation Capacity Increased 20%	E134-E137
Scenario 8C	18 Dry Ton HES Yields with Irrigation, both Capital and Operating Costs Reduced 15% using Part-Time Labor, Trafficable Days at 50%, and Transportation Capacity Increased 20%	E138-E141

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Table E1, continued.

Scenario	Description of Scenario	Cost per Dry Ton of All Biomass feedstock Produced
Scenario 9A	HES rotation acreage sub-leasing costs increased to evaluate prospects of greater returns during non-HES years	E142-E145
Scenario 9B	Irrigation wells are owned, but not operated	E146-E149
Scenario 9C	SG harvesting is prohibited during April and May	E150-E153
Scenario 9D	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Year 2 Baseline Scenario	E154-E157
Scenario 9E	Integer programming requirements disabled for all machinery and equipment purchases, full-time labor hires, etc. for the Economies of Size Scenario 6E	E158-E161

Table E2. Critical Results for Sensitivity Scenario 1A (Extra Three Periods Supply), Basis for Comparison in Subsequent Sensitivity Scenario Analyses, Hypothetical Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 1A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	43,950	7,105	19.28%
Acres of SG	37,225	37,596	371	1.00%
Total Farm Acres[d]	187,760	209,446	21,686	11.55%
HES Dry Ton Production	313,266	373,159	59,893	19.12%
HES Wet Ton Production	950,719	1,128,799	178,080	18.73%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.49	(0.01)	(0.11%)
Average SG Dry Ton Yield per Acre	2.69	2.66	(0.03)	(1.22%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$62,187,298	$8,585,095	16.02%
Cost per Acre of All Biomass feedstock Produced	723.67	762.60	38.93	5.38%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	155.47	21.46	16.01%
Cost per Gallon of Fuel	1.7867	2.0729	0.2862	16.02%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$136,085,244	$17,835,949	15.08%
Annualized Investment Costs	14,919,357	17,244,696	2,325,399	15.59%
Percent of All Costs	27.8%	27.7%	(0.1%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	211.47	10.05	4.02%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	43.11	5.81	15.58%
Cost per Gallon of Fuel	0.4973	0.5748	0.0775	15.59%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$44,942,602	$6,259,757	16.18%
Percent of All Costs	72.2%	72.3%	0.1%	--
Cost per Acre of All Biomass feedstock Produced	522.25	551.13	28.88	5.53%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	112.36	15.65	16.18%
Cost per Gallon of Fuel	1.2894	1.4981	0.2087	16.18%

[a] In this scenario, an extra three periods supply of biomass feedstock is produced. This is the only variable changed from the Year 2 Baseline Scenario.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E3. Sensitivity Scenario 1A (Extra Three Periods Supply) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	266,181	sq ft	$ 122,443	$ 32,969	0.19%
Office Space	8,155	sq ft	1,223,250	214,945	1.25%
Pole Barns	98,683	sq ft	1,381,562	242,763	1.41%
Inside Machinery Storage	30,330	sq ft	3,639,600	639,537	3.71%
Headquarters Land	274,336	sq ft	31,274	2,736	0.02%
Purchased Machinery					
Tractor Size 1	26	#	4,486,560	858,999	4.98%
Tractor Size 2	45	#	5,942,250	970,047	5.63%
Planter	8	#	527,072	301,789	1.75%
Harvester	16	#	5,913,814	1,458,062	8.46%
In-Field Buggy	58	#	2,117,000	335,155	1.94%
Transport Trucks	136	#	14,416,000	2,332,014	13.52%
High-Energy Sorghum Trailers	136	#	7,058,400	801,847	4.65%
Switchgrass Trailers	17	#	595,000	74,166	0.43%
Support Vehicles	31	#	1,085,000	258,951	1.50%
Storage Handling	42	#	5,167,050	695,835	4.04%
Disc	10	#	449,962	124,454	0.72%
Bedder	16	#	318,400	34,163	0.20%
Fertilizer Toolbar	9	#	135,000	24,045	0.14%
Cultivator	3	#	283,500	67,084	0.39%
Sprayer	2	#	453,256	79,564	0.46%
Hay Cutter	5	#	579,315	136,271	0.79%
Wheel Rake	3	#	64,875	19,249	0.11%
Square Baler	6	#	581,814	99,356	0.58%
Hipper	13	#	310,765	55,350	0.32%
Rolling Cultivator	4	#	121,160	34,293	0.20%
Land Plane	10	#	395,000	106,067	0.62%
Bale Wagon	12	#	1,745,184	371,483	2.15%
Hay Squeeze	10	#	1,365,250	281,010	1.63%
Irrigation					
Develop Irrigation Well Size 2	87	#	22,986,488	1,855,383	10.76%
Re-Lift Pump	293	#	5,054,250	482,294	2.80%
SG Custom Establishment					
SG Harvest Production	37,596	acres	11,214,887	825,013	4.78%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.09%
Storage					
Storage Land	8,273,920	sq ft	1,654,784	257,677	1.49%
Purchase Storage	202	#	21,533,200	1,978,450	11.47%
Silo Cover	4,799,520	sq ft	1,199,880	315,909	1.83%
Total Cost			$136,085,244	$17,244,696	100.00%

Table E4. Sensitivity Scenario 1A (Extra Three Periods Supply) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$1,118,056	2.49%
Land				
HES Land	acres	43,950	2,527,125	5.62%
SG Production Land	acres	37,596	845,910	1.88%
SG Insurance Land	acres	40,000	700,000	1.56%
Labor				
Hire Full-Time Labor	persons	210	10,274,775	22.86%
Hire Part-Time Labor	hours	40,807	550,543	1.22%
Irrigation				
Pump Groundwater	acre-inches	732,643	4,101,404	9.13%
HES Field Operations				
Disc	n/a	n/a	154,403	0.34%
Disc	n/a	n/a	154,403	0.34%
Land Plane	n/a	n/a	258,070	0.57%
Bed	n/a	n/a	81,695	0.18%
Hip Beds	n/a	n/a	84,554	0.19%
Fertilize	n/a	n/a	8,333,267	18.54%
Hip Beds	n/a	n/a	84,554	0.19%
Spray	n/a	n/a	526,335	1.17%
Condition Beds	n/a	n/a	87,326	0.19%
Always Planting	n/a	n/a	1,752,958	3.90%
Cultivate	n/a	n/a	97,799	0.22%
Always Harvesting	n/a	n/a	2,356,727	5.24%
Support Vehicles	n/a	n/a	29,682	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,422,603	7.62%
Transportation				
Transport HES	wet tons	1,128,799	2,677,033	5.96%
Transport SG	dry tons	100,000	353,171	0.79%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	8,274	82,999	0.18%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,836	67,429	0.15%
Overhead Management				
Overhead Management	persons	50	4,219,745	9.39%
Total cost			$44,942,602	100.00%

Table E5. Summary of Sensitivity Scenario 1A (Extra Three Periods Supply), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Costs per Dry Ton of Biomass feedstock[c]	Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$17,244,696	$211.47	$43.11	$0.5748	27.73%
Annual Operating Costs	44,942,602	551.13	112.36	1.4981	72.27%
Total Cost	$62,187,298	$762.60	$155.47	$2.0729	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E6. Critical Results for Sensitivity Scenario 1B (SG Insurance Acreage for 25% Supply), Basis for Comparison in Subsequent Sensitivity Scenario Analyses, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 1B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,845	0	0.00%
Acres of SG	37,225	37,225	0	0.00%
Total farm acres[d]	187,760	187,760	0	0.00%
HES Dry Ton Production	313,266	313,266	0	0.00%
HES Wet Ton Production	950,719	950,719	0	0.00%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.50	0.00	0.03%
Average SG Dry Ton Yield per Acre	2.69	2.69	0.00	(0.14%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$52,006,548	($1,595,655)	(2.98%)
Cost per Acre of All Biomass feedstock Produced	723.67	702.13	(21.54)	(2.98%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	130.02	(3.99)	(2.98%)
Cost per Gallon of Fuel	1.7867	1.7336	(0.0531)	(2.97%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$106,317,209	($11,932,086)	(10.09%)
Annualized Investment Costs	14,919,357	14,041,567	(877,790)	(5.88%)
Percent of All Costs	27.8%	27.0%	(0.8%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	189.57	(11.85)	(5.88%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	35.10	(2.20)	(5.89%)
Cost per Gallon of Fuel	0.4973	0.4681	(0.0292)	(5.88%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$37,964,981	($717,864)	(1.86%)
Percent of All Costs	72.2%	73.0%	0.8%	--
Cost per Acre of All Biomass feedstock Produced	522.25	512.56	(9.69)	(1.86%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	94.91	(1.80)	(1.86%)
Cost per Gallon of Fuel	1.2894	1.2655	(0.0239)	(1.85%)

[a] In this scenario, no SG is established for insurance purposes. That is, the 40,000 acres of land that is established for yield insurance under the baseline scenario is removed.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E7. Sensitivity Scenario 1B (SG Insurance Acreage for 25% Supply) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	233,881	sq ft	$107,585	$28,969	0.21%
Office Space	7,407	sq ft	1,111,050	195,230	1.39%
Pole Barns	87,315	sq ft	1,222,410	214,797	1.53%
Inside Machinery Storage	25,922	sq ft	3,110,640	546,590	3.89%
Headquarters Land	241,288	sq ft	27,507	2,406	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	4.94%
Tractor Size 2	37	#	4,885,850	797,594	5.68%
Tractor Size 3	0	#	0	0	0.00%
Planter	7	#	461,188	264,065	1.88%
Harvester	13	#	4,804,974	1,184,676	8.44%
In-Field Buggy	49	#	1,788,500	283,148	2.02%
Transport Trucks	115	#	12,190,000	1,971,923	14.04%
High-Energy Sorghum Trailers	115	#	5,968,500	678,032	4.83%
Switchgrass Trailers	20	#	700,000	87,254	0.62%
Support Vehicles	26	#	910,000	217,185	1.55%
Storage Handling	34	#	4,182,850	563,295	4.01%
Disc	8	#	359,970	99,563	0.71%
Bedder	13	#	258,700	27,758	0.20%
Fertilizer Toolbar	8	#	120,000	21,373	0.15%
Cultivator	3	#	283,500	67,084	0.48%
Sprayer	1	#	226,628	39,782	0.28%
Hay Cutter	6	#	695,178	163,525	1.16%
Wheel Rake	4	#	86,500	25,665	0.18%
Square Baler	8	#	775,752	132,474	0.94%
Hipper	14	#	334,670	59,608	0.42%
Rolling Cultivator	4	#	121,160	34,293	0.24%
Land Plane	8	#	316,000	84,854	0.60%
Bale Wagon	15	#	2,181,480	464,354	3.31%
Hay Squeeze	12	#	1,638,300	337,212	2.40%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	11.85%
Re-Lift Pump	246	#	4,243,500	404,930	2.88%
SG Custom Establishment					
SG Harvest Production	37,225	acres	11,104,147	816,867	5.82%
SG Insurance Production	0	acres	0	0	0.00%
Storage					
Storage Land	6,062,080	sq ft	1,212,416	188,793	1.34%
Purchase Storage	148	#	15,776,800	1,449,558	10.32%
Silo Cover	3,516,480	sq ft	879,120	231,458	1.65%
Total Cost			$106,317,209	$14,041,567	100.00%

Table E8. Sensitivity Scenario 1B (SG Insurance Acreage for 25% Supply) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		944,413	2.49%
Land				
HES Land	acres	36,845	2,118,588	5.58%
SG Production Land	acres	37,225	837,563	2.21%
SG Insurance Land	acres	0	0	0.00%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.91%
Hire Part-Time Labor	hours	38	544,461	1.43%
Irrigation				
Pump Groundwater	acre-inches		3,438,341	9.06%
HES Field Operations				
Disc	n/a	n/a	129,441	0.34%
Disc	n/a	n/a	129,441	0.34%
Land Plane	n/a	n/a	216,349	0.57%
Bed	n/a	n/a	68,488	0.18%
Hip Beds	n/a	n/a	70,884	0.19%
Fertilize	n/a	n/a	6,986,051	18.40%
Hip Beds	n/a	n/a	70,884	0.19%
Spray	n/a	n/a	441,244	1.16%
Condition Beds	n/a	n/a	73,209	0.19%
Always Planting	n/a	n/a	1,469,562	3.87%
Cultivate	n/a	n/a	81,988	0.22%
Always Harvesting	n/a	n/a	1,979,530	5.21%
Support Vehicles	n/a	n/a	24,884	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,395,417	8.94%
Transportation				
Transport HES	wet ton	950,719	2,255,441	5.94%
Transport SG	dry tons	100,000	353,171	0.93%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,408	74,309	0.20%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,739	66,763	0.18%
Overhead Management				
Overhead Management	persons	46	3,876,855	10.21%
Total cost			$37,964,981	100.00%

Table E9. Summary of Sensitivity Scenario 1B (SG Insurance Acreage for 25% Supply), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$14,041,567	$189.57	$35.10	$0.4681	27.00%
Annual Operating Costs	37,964,981	512.56	94.91	1.2655	73.00%
Total Cost	$52,006,548	$702.13	$130.02	$1.7336	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E10. Critical Results for Sensitivity Scenario 2A (Lower HES Yields and No Irrigation), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 2A[a] Results	Change	% Change[b,c]
Production Levels				
Acre of HES	36,845	56,422	19,577	53.13%
Acres of SG	37,225	37,639	414	1.11%
Total Farm Acres[d]	187,760	246,905	59,145	31.50%
HES Dry Ton Production	313,266	315,405	2,139	0.68%
HES Wet Ton Production	950,719	966,385	15,666	1.65%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	5.59	(2.91)	(34.23%)
Average SG Dry Ton Yield per Acre	2.69	2.66	(0.03)	(1.23%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$53,146,483	($455,720)	(0.85%)
Cost per Acre of All Biomass feedstock Produced	723.67	565.02	(158.65)	(21.92%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	132.87	(1.14)	(0.85%)
Cost per Gallon of Fuel	1.7867	1.7715	(0.0152)	(0.85%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$97,933,958	($20,315,337)	(17.18%)
Annualized Investment Costs	14,919,357	13,856,129	(1,063,228)	(7.13%)
Percent of All Costs	27.8%	26.1%	(1.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	147.31	(54.11)	(26.86%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	34.64	(2.66)	(7.13%)
Cost per Gallon of Fuel	0.4973	0.4619	(0.0354)	(7.12%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$39,290,354	$607,509	1.57%
Percent of All Costs	72.2%	73.9%	1.7	--
Cost per Acre of All Biomass feedstock Produced	522.25	417.71	(104.54)	(20.02%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	98.23	1.52	1.57%
Cost per Gallon of Fuel	1.2894	1.3097	0.0813	1.57%

[a] In this scenario, HES maximum-expected yields are reduced to 8 dry tons per acre and irrigation requirements are removed. It is assumed that decreased expected yields reduce fertilizer nutrients requirements as less tonnage is expected to be removed per acre than under the baseline scenario assumptions.
[b] Negative represents a reduction while a positive represents an increase in the variable relative to the base situations.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E11. Sensitivity Scenario 2A (Lower HES Yields and No Irrigation) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	271,265	sq ft	$ 124,782	$ 33,599	0.24%
Office Space	9,407	sq ft	1,411,050	247,944	1.79%
Pole Barns	100,059	sq ft	1,400,826	246,148	1.78%
Inside Machinery Storage	30,870	sq ft	3,704,400	650,923	4.70%
Headquarters Land	280,672	sq ft	31,997	2,799	0.02%
Purchased Machinery					
Tractor Size 1	29	#	5,004,240	958,114	6.91%
Tractor Size 2	40	#	5,282,000	862,264	6.22%
Planter	10	#	658,840	377,236	2.72%
Harvester	16	#	5,913,814	1,458,062	10.52%
In-Field Buggy	53	#	1,934,500	306,262	2.21%
Transport Trucks	112	#	11,872,000	1,920,482	13.86%
High-Energy Sorghum Trailers	112	#	5,812,800	660,344	4.77%
Switchgrass Trailers	17	#	595,000	74,166	0.54%
Support Vehicles	40	#	1,400,000	334,131	2.41%
Storage Handling	35	#	4,305,875	579,863	4.18%
Disc	13	#	584,950	161,790	1.17%
Bedder	17	#	338,300	36,298	0.26%
Fertilizer Toolbar	12	#	180,000	32,060	0.23%
Cultivator	4	#	378,000	89,445	0.65%
Sprayer	2	#	453,256	79,564	0.57%
Hay Cutter	5	#	579,315	136,271	0.98%
Wheel Rake	3	#	64,875	19,249	0.14%
Square Baler	6	#	581,814	99,356	0.72%
Hipper	17	#	406,385	72,381	0.52%
Rolling Cultivator	6	#	181,740	51,439	0.37%
Land Plane	12	#	474,000	127,281	0.92%
Bale Wagon	12	#	1,745,184	371,483	2.68%
Hay Squeeze	10	#	1,365,250	281,010	2.03%
Irrigation					
Develop Irrigation Well Size 2	0	#	0.00	0.00	0.00%
Re-Lift Pump	0	#	0.00	0.00	0.00%
SG Custom Establishment					
SG Harvest Production	37,639	acres	11,227,698	825,956	5.96%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.33%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.37%
Purchase Storage	149	#	15,883,400	1,459,352	10.53%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.68%
Total Cost			$97,933,958	$13,856,129	100.00%

Table E12. Sensitivity Scenario 2A (Lower HES Yields and No Irrigation) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 977,396	2.49%
Land				
HES Land	acres	56,422	3,244,265	8.26%
SG Production Land	acres	37,639	846,878	2.16%
SG Insurance Land	acres	40,000	700,000	1.78%
Labor				
Hire Full-Time Labor	persons	180	8,806,950	22.42%
Hire Part-Time Labor	hours	37,638	507,787	1.29%
Irrigation				
Pump Groundwater	acre-inches	0	$0.00	0.00%
HES Field Operations				
Disc	n/a	n/a	198,220	0.50%
Disc	n/a	n/a	198,220	0.50%
Land Plane	n/a	n/a	331,306	0.84%
Bed	n/a	n/a	104,879	0.27%
Hip Beds	n/a	n/a	108,549	0.28%
Fertilize	n/a	n/a	7,177,371	18.27%
Hip Beds	n/a	n/a	108,549	0.28%
Spray	n/a	n/a	675,700	1.72%
Condition Beds	n/a	n/a	112,108	0.29%
Always Planting	n/a	n/a	2,250,417	5.73%
Cultivate	n/a	n/a	125,553	0.32%
Always Harvesting	n/a	n/a	2,608,664	6.64%
Support Vehicles	n/a	n/a	38,106	0.10%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,425,748	8.72%
Transportation				
Transport HES	wet tons	966,385	2,287,522	5.82%
Transport SG	dry tons	100,000	353,171	0.90%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,264	72,868	0.19%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,847	67,506	0.17%
Overhead Management				
Overhead Management	persons	47	3,962,577	10.09%
Total cost			$39,290,354	100.00%

Table E13. Summary of Sensitivity Scenario 2A (Lower HES Yields and No Irrigation), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$13,856,129	$147.31	$ 34.64	$0.4619	26.07%
Annual Operating Costs	39,290,354	417.71	98.23	1.3097	73.93%
Total Cost	$53,146,483	$565.02	$132.87	$1.7715	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E14. Critical Results for Sensitivity Scenario 2B (HES Yields Maintained with No Irrigation), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 2B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	38,269	1,424	3.86%
Acres of SG	37,225	37,675	450	1.21%
Total Farm Acres[d]	187,760	192,482	4,722	2.51%
HES Dry Ton Production	313,266	315,434	2,168	0.69%
HES Wet Ton Production	950,719	964,475	13,756	1.45%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.24	(0.26)	(3.03%)
Average SG Dry Ton Yield per Acre	2.69	2.65	(0.04)	(1.33%)
Total Capital Investment and Operating Costs				
Annual Cost	$53,602,203	$47,531,456	($6,070,747)	(11.33%)
Cost per Acre of All Biomass feedstock Produced	723.67	625.88	(97.79)	(13.51%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	118.83	(15.18)	(11.33%)
Cost per Gallon of Fuel	1.7867	1.5844	(0.2023)	(11.32%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$90,678,435	($27,570,860)	(23.32%)
Annualized Investment Costs	14,919,357	12,341,859	(2,577,49)	(17.28%)
Percent of All Costs	27.8%	26.0%	(1.8%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	162.51	(38.91)	(19.32%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	30.85	(6.45)	(17.28%)
Cost per Gallon of Fuel	0.4973	0.4114	(0.0859)	(17.27%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$35,189,598	($3,493,247)	(9.03%)
Percent of All Costs	72.2%	74.0%	1.8%	--
Cost per Acre of All Biomass feedstock Produced	522.25	463.36	(58.89)	(11.28%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	87.97	(8.74)	(9.03%)
Cost per Gallon of Fuel	1.2894	1.1730	(0.1164)	(9.03%)

[a] In this scenario, HES yields remain unchanged from the Year 2 Baseline Scenario (12 dry tons per acre). The only change is that irrigation requirements and all associated costs are removed.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E15. Sensitivity Scenario 2B (HES Yields Maintained with No Irrigation) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	221,651	sq ft	$101,959	27,454	0.22%
Office Space	7,595	sq ft	1,139,250	200,185	1.62%
Pole Barns	82,247	sq ft	1,151,458	202,330	1.64%
Inside Machinery Storage	24,781	sq ft	2,973,720	522,531	4.23%
Headquarters Land	229,246	sq ft	26,134	2,286	0.02%
Purchased Machinery					
Tractor Size 1	20	#	3,451,200	660,768	5.35%
Tractor Size 2	37	#	4,885,850	797,594	6.46%
Planter	7	#	461,188	264,065	2.14%
Harvester	12	#	4,435,360	1,093,547	8.86%
In-Field Buggy	46	#	1,679,000	265,812	2.15%
Transport Trucks	108	#	11,448,000	1,851,893	15.00%
High-Energy Sorghum Trailers	108	#	5,605,200	636,760	5.16%
Switchgrass Trailers	17	#	595,000	74,166	0.60%
Support Vehicles	27	#	945,000	225,538	1.83%
Storage Handling	33	#	4,059,825	546,728	4.43%
Disc	9	#	404,966	112,008	0.91%
Bedder	12	#	238,800	25,622	0.21%
Fertilizer Toolbar	8	#	120,000	21,373	0.17%
Cultivator	3	#	283,500	67,084	0.54%
Sprayer	2	#	453,256	79,564	0.64%
Hay Cutter	5	#	579,315	136,271	1.10%
Wheel Rake	3	#	64,875	19,249	0.16%
Square Baler	6	#	581,814	99,356	0.81%
Hipper	12	#	286,860	51,092	0.41%
Rolling Cultivator	4	#	121,160	34,293	0.28%
Land Plane	8	#	316,000	84,854	0.69%
Bale Wagon	12	#	1,745,184	371,483	3.01%
Hay Squeeze	10	#	1,365,250	281,010	2.28%
Irrigation					
Develop Irrigation Well Size 2	0	#	0.00	0.00	0.00%
Re-Lift Pump	0	#	0.00	0.00	0.00%
SG Custom Establishment					
SG Harvest Production	37,674	acres	11,238,243	826,731	6.70%
SG Insurance Production	40,000	acres	11,932,000	877,767	7.11%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.54%
Purchase Storage	149	#	15,883,400	1,459,352	11.82%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.89%
Total Cost			$90,678,435	$12,341,859	100.00%

Table E16. Sensitivity Scenario 2B (HES Yields Maintained with No Irrigation) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 875,346	2.49%
Land				
HES Land	acres	38,269	2,200,468	6.25%
SG Production Land	acres	37,675	847,688	2.41%
SG Insurance Land	acres	40,000	700,000	1.99%
Labor				
Hire Full-Time Labor	persons	160	7,828,400	22.25%
Hire Part-Time Labor	hours	42,627	575,102	1.63%
Irrigation				
Pump Groundwater	acre-inches	0	0.00	0.00%
HES Field Operations				
Disc	n/a	n/a	134,445	0.38%
Disc	n/a	n/a	134,445	0.38%
Land Plane	n/a	n/a	224,711	0.64%
Bed	n/a	n/a	71,135	0.20%
Hip Beds	n/a	n/a	73,624	0.21%
Fertilize	n/a	n/a	7,256,080	20.62%
Hip Beds	n/a	n/a	73,624	0.21%
Spray	n/a	n/a	458,300	1.30%
Condition Beds	n/a	n/a	76,038	0.22%
Always Planting	n/a	n/a	1,526,365	4.34%
Cultivate	n/a	n/a	85,158	0.24%
Always Harvesting	n/a	n/a	2,036,190	5.79%
Support Vehicles	n/a	n/a	25,845	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,428,336	9.74%
Transportation				
Transport HES	wet tons	964,475	2,284,401	6.49%
Transport SG	dry tons	100,000	353,171	1.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	6,180	61,997	0.18%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,857	67,569	0.19%
Overhead Management				
Overhead Management	persons	45	3,791,132	10.77%
Total cost			$35,189,598	100.00%

Table E17. Summary of Sensitivity Scenario 2B (HES Yields Maintained with No Irrigation), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$12,341,859	$162.51	$ 30.85	$0.4114	25.97%
Annual Operating Costs	35,189,598	463.36	87.97	1.1730	74.03%
Total Cost	$47,531,456	$625.88	$118.83	$1.5844	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E18. Critical Results for Sensitivity Scenario 2C (Increased HES Yields of 18 tons/ac), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 2C[a] Results	Change	% Change[b,c]
Production Levels				
Acre of HES	36,845	25,787	(11,058)	(30.01%)
Acres of SG	37,225	37,559	334	0.90%
Total farm acres[d]	187,760	154,920	(32,840)	(17.49%)
HES Dry Ton Production	313,266	315,269	2,003	0.64%
HES Wet Ton Production	950,719	959,426	8,707	0.92%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	12.23	3.73	43.83%
Average SG Dry Ton Yield per Acre	2.69	2.66	(0.03)	(1.02%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$47,847,508	(5,754,695)	(10.74%)
Cost per Acre of All Biomass feedstock Produced	723.67	755.34	31.67	4.38%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	119.62	(14.39)	(10.74%)
Cost per Gallon of Fuel	1.7867	1.5949	(0.1918)	(10.73%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$103,947,172	(14,302,123)	(12.09%)
Annualized Investment Costs	14,919,357	12,867,140	(2,052,217)	(13.76%)
Percent of All Costs	27.8%	26.9%	(0.9%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	203.12	1.70	0.85%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	32.17	(5.13)	(13.76%)
Cost per Gallon of Fuel	0.4973	0.4289	(0.0684)	(13.75%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$34,980,368	(3,702,477)	(9.57%)
Percent of All Costs	72.2%	73.1%	0.9%	--
Cost per Acre of All Biomass feedstock Produced	522.25	552.21	29.96	5.74%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	87.45	(9.26)	(9.57%)
Cost per Gallon of Fuel	1.2894	1.1660	(0.1234)	(9.57%)

[a] In this scenario, HES maximum-expected yields are increased to 18 dry tons per acre while irrigation requirements are maintained at levels specified in the baseline scenario. It is assumed that the expected increase in yields increases fertilizer nutrients requirements as more tonnage is expected to be removed per acre than under the baseline scenario assumptions.

[b] Negative represents a reduction while a positive represents an increase in the variable relative to the base situations.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E19. Sensitivity Scenario 2C (Increased HES Yields of 18 tons/ac) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	193,525	sq ft	$ 89,022	$ 23,970	0.19%
Office Space	6,335	sq ft	950,250	166,974	1.30%
Pole Barns	73,119	sq ft	1,023,666	179,875	1.40%
Inside Machinery Storage	20,476	sq ft	2,457,120	431,756	3.36%
Headquarters Land	199,860	sq ft	22,784	1,993	0.02%
Purchased Machinery					
Tractor Size 1	15	#	2,588,400	495,576	3.85%
Tractor Size 2	35	#	4,621,750	754,481	5.86%
Planter	5	#	329,420	188,618	1.47%
Harvester	9	#	3,326,520	820,160	6.37%
In-Field Buggy	42	#	1,533,000	242,698	1.89%
Transport Trucks	107	#	11,342,000	1,834,746	14.26%
High-Energy Sorghum Trailers	107	#	5,553,300	630,865	4.90%
Switchgrass Trailers	17	#	595,000	74,166	0.58%
Support Vehicles	19	#	665,000	158,712	1.23%
Storage Handling	34	#	4,182,850	563,295	4.38%
Disc	8	#	359,970	99,563	0.77%
Bedder	9	#	179,100	19,217	0.15%
Fertilizer Toolbar	6	#	90,000	16,030	0.12%
Cultivator	2	#	189,000	44,722	0.35%
Sprayer	1	#	226,628	39,782	0.31%
Hay Cutter	5	#	579,315	136,271	1.06%
Wheel Rake	3	#	64,875	19,249	0.15%
Square Baler	6	#	581,814	99,356	0.77%
Hipper	8	#	191,240	34,062	0.26%
Rolling Cultivator	3	#	90,870	25,720	0.20%
Land Plane	6	#	237,000	63,640	0.49%
Bale Wagon	12	#	1,745,184	371,483	2.89%
Hay Squeeze	10	#	1,365,250	281,010	2.18%
Irrigation					
Develop Irrigation Well Size 2	56	#	14,795,900	1,194,269	9.28%
Re-Lift Pump	172	#	2,967,000	283,122	2.20%
SG Custom Establishment					
SG Harvest Production	37,558	acres	11,203,609	824,184	6.41%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.82%
Storage					
Storage Land	6,062,080	sq ft	1,212,416	188,793	1.47%
Purchase Storage	148	#	15,776,800	1,449,558	11.27%
Silo Cover	3,516,480	sq ft	879,120	231,458	1.80%
Total Cost			$103,947,172	$12,867,140	100.00%

Table E20. Sensitivity Scenario 2C (Increased HES Yields of 18 tons/ac) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 870,139	2.49%
Land				
HES Land	acres	25,787	1,482,753	4.24%
SG Production Land	acres	37,559	845,078	2.42%
SG Insurance Land	acres	40,000	700,000	2.00%
Labor				
Hire Full-Time Labor	persons	150	7,339,125	20.98%
Hire Part-Time Labor	hours	42,832	577,868	1.65%
Irrigation				
Pump Groundwater	acre-inches	429,869	2,406,449	6.88%
HES Field Operations				
Disc	n/a	n/a	90,594	0.26%
Disc	n/a	n/a	90,594	0.26%
Land Plane	n/a	n/a	151,420	0.43%
Bed	n/a	n/a	47,934	0.14%
Hip Beds	n/a	n/a	49,611	0.14%
Fertilize	n/a	n/a	7,303,106	20.88%
Hip Beds	n/a	n/a	49,611	0.14%
Spray	n/a	n/a	308,821	0.88%
Condition Beds	n/a	n/a	51,238	0.15%
Always Planting	n/a	n/a	1,028,527	2.94%
Cultivate	n/a	n/a	57,383	0.16%
Always Harvesting	n/a	n/a	1,639,347	4.69%
Support Vehicles	n/a	n/a	17,416	0.05%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,419,834	9.78%
Transportation				
Transport HES	wet tons	959,426	2,274,971	6.50%
Transport SG	dry tons	100,000	353,171	1.01%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	5,243	52,590	0.15%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,826	67,361	0.19%
Overhead Management				
Overhead Management	persons	44	3,705,410	10.59%
Total cost			$34,980,368	100.00%

Table E21. Summary of Sensitivity Scenario 2C (Increased HES Yields of 18 tons/ac), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$12,867,140	$203.12	$ 32.17	$0.4289	26.89%
Annual Operating Costs	34,980,368	552.21	87.45	1.1660	73.11%
Total Cost	$47,847,508	$755.34	$119.62	$1.5949	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E22. Critical Results for Sensitivity Scenario 2D (Increased HES Yields of 25 tons/ac), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 2D[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	18,327	(18,518)	(50.26%)
Acres of SG	37,225	37,802	577	1.55%
Total farm acres[d]	187,760	132,783	(54,977)	(29.28%)
HES Dry Ton Production	313,266	316,709	3,443	1.10%
HES Wet Ton Production	950,719	966,381	15,662	1.65%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	17.28	8.78	103.31%
Average SG Dry Ton Yield per Acre	2.69	2.65	(0.04)	(1.66%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$44,615,426	($8,986,777)	(16.77%)
Cost per Acre of All Biomass feedstock Produced	$723.67	$794.87	$71.20	9.84%
Cost per Dry Ton of All Biomass feedstock Produced	$134.01	$111.54	($22.47)	(16.77%)
Cost per Gallon of Fuel	$1.7867	$1.4872	($0.2995)	(16.76%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$96,645,315	($21,603,980)	(18.27%)
Annualized Investment Costs	$14,919,357	$11,735,908	($3,183,449)	(21.34%)
Percent of All Costs	27.8%	26.3%	(1.5%)	--
Cost per Acre of All Biomass feedstock Produced	$201.42	$209.09	$7.67	3.81%
Cost per Dry Ton of All Biomass feedstock Produced	$37.30	$29.34	($7.96)	(21.34%)
Cost per Gallon of Fuel	$0.4973	$0.3912	($0.1061)	(21.34%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$32,879,517	($5,803,328)	(15.00%)
Percent of All Costs	72.2%	73.7%	1.5%	--
Cost per Acre of All Biomass feedstock Produced	$522.25	$585.78	$63.53	12.17%
Cost per Dry Ton of All Biomass feedstock Produced	$96.71	$82.20	($14.51)	(15.00%)
Cost per Gallon of Fuel	$1.2894	$1.0960	($0.1934)	(15.00%)

[a] In this scenario, HES maximum-expected yields are increased to 25 dry tons per acre while irrigation requirements are maintained at levels specified in the baseline scenario. It is assumed that the expected increase in yields increases fertilizer nutrients requirements as more tonnage is expected to be removed per acre than under the baseline scenario assumptions.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E23. Sensitivity Scenario 2D (Increased HES Yields of 25 tons/ac) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	167,639	sq ft	$ 77,114	$ 20,764	0.18%
Office Space	5,613	sq ft	841,950	147,944	1.26%
Pole Barns	64,172	sq ft	898,408	157,865	1.35%
Inside Machinery Storage	16,841	sq ft	2,020,920	355,108	3.03%
Headquarters Land	173,252	sq ft	19,751	1,728	0.01%
Purchased Machinery					
Tractor Size 1	10	#	1,725,600	330,384	2.82%
Tractor Size 2	36	#	4,753,800	776,038	6.61%
Planter	4	#	263,536	150,894	1.29%
Harvester	6	#	2,217,680	546,773	4.66%
In-Field Buggy	42	#	1,533,000	242,698	2.07%
Transport Trucks	111	#	11,766,000	1,903,335	16.22%
High-Energy Sorghum Trailers	111	#	5,760,900	654,448	5.58%
Switchgrass Trailers	14	#	490,000	61,077	0.52%
Support Vehicles	13	#	455,000	108,592	0.93%
Storage Handling	33	#	4,059,825	546,728	4.66%
Disc	4	#	179,985	49,781	0.42%
Bedder	6	#	119,400	12,811	0.11%
Fertilizer Toolbar	4	#	60,000	10,687	0.09%
Cultivator	2	#	189,000	44,722	0.38%
Sprayer	1	#	226,628	39,782	0.34%
Hay Cutter	4	#	463,452	109,017	0.93%
Wheel Rake	3	#	64,875	19,249	0.16%
Square Baler	5	#	484,845	82,797	0.71%
Hipper	6	#	143,430	25,546	0.22%
Rolling Cultivator	2	#	60,580	17,146	0.15%
Land Plane	4	#	158,000	42,427	0.36%
Bale Wagon	10	#	1,454,320	309,569	2.64%
Hay Squeeze	8	#	1,092,200	224,808	1.92%
Irrigation					
Develop Irrigation Well Size 2	44	#	11,625,350	938,355	8.00%
Re-Lift Pump	123	#	2,121,750	202,465	1.73%
SG Custom Establishment					
SG Harvest Production	37,802	acres	11,276,217	829,525	7.07%
SG Insurance Production	40,000	acres	11,932,000	877,767	7.48%
Storage					
Storage Land	6,144,000	sq ft	1,228,800	191,344	1.63%
Purchase Storage	150	#	15,990,000	1,469,146	12.52%
Silo Cover	3,564,000	sq ft	891,000	234,586	2.00%
Total Cost			$96,645,315	$11,735,908	100.00%

Table E24. Sensitivity Scenario 2D (Increased HES Yields of 25 tons/ac) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 817,857	2.49%
Land				
HES Land	acres	18,327	1,053,803	3.21%
SG Production Land	acres	37,802	850,545	2.59%
SG Insurance Land	acres	40,000	700,000	2.13%
Labor				
Hire Full-Time Labor	persons	150	7,339,125	22.32%
Hire Part-Time Labor	hours	39,779	536,672	1.63%
Irrigation				
Pump Groundwater	acre-inches	305,507	1,710,256	5.20%
HES Field Operations				
Disc	n/a	n/a	64,385	0.20%
Disc	n/a	n/a	64,385	0.20%
Land Plane	n/a	n/a	107,613	0.33%
Bed	n/a	n/a	34,066	0.10%
Hip Beds	n/a	n/a	35,258	0.11%
Fertilize	n/a	n/a	7,191,578	21.87%
Hip Beds	n/a	n/a	35,258	0.11%
Spray	n/a	n/a	219,478	0.67%
Condition Beds	n/a	n/a	36,414	0.11%
Always Planting	n/a	n/a	730,971	2.22%
Cultivate	n/a	n/a	40,782	0.12%
Always Harvesting	n/a	n/a	1,410,767	4.29%
Support Vehicles	n/a	n/a	12,377	0.04%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,437,659	10.46%
Transportation				
Transport HES	wet tons	966,381	2,289,859	6.96%
Transport SG	dry tons	100,000	353,171	1.07%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,391	34,015	0.10%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,890	67,797	0.21%
Overhead Management				
Overhead Management	persons	44	3,705,410	11.27%
Total cost			$32,879,517	100.00%

Table E25. Summary of Sensitivity Scenario 2D (Increased HES Yields of 25 tons/ac), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$11,735,908	$209.09	$ 29.34	$0.3912	26.30%
Annual Operating Costs	32,879,517	585.78	82.20	1.0960	73.70%
Total Cost	$44,615,426	$794.87	$111.54	$1.4872	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E26. Critical Results for Sensitivity Scenario 3A (Maximum-expected SG Yield is Set at 2 Dry Tons per Acre)[a], Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 3A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,864	19	0.05%
Acres of SG	37,225	56,222	18,997	51.03%
Total farm acres[d]	187,760	221,814	34,054	18.14%
HES Dry Ton Production	313,266	314,693	1,427	0.46%
HES Wet Ton Production	950,719	954,472	3,753	0.39%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.54	0.04	0.43%
Average SG Dry Ton Yield per Acre	2.69	1.78	(0.91)	(33.88%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$56,261,663	$2,659,460	4.96%
Cost per Acre of All Biomass feedstock Produced	723.67	604.41	(119.26)	(16.48%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	140.65	6.64	4.96%
Cost per Gallon of Fuel	1.7867	1.8754	0.0887	4.96%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$130,486,279	$12,236,984	10.35%
Annualized Investment Costs	14,919,357	15,963,162	1,043,805	7.00%
Percent of All Costs	27.8%	28.4%	0.6%	--
Cost per Acre of All Biomass feedstock Produced	201.42	171.49	(29.93)	(14.86%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	39.91	2.61	6.99%
Cost per Gallon of Fuel	0.4973	0.5321	0.03	7.00%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$40,298,501	$1,615,656	4.18%
Percent of All Costs	72.2%	71.6%	(0.6%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	432.92	(89.33)	(17.11%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	100.75	4.04	4.17%
Cost per Gallon of Fuel	1.2894	1.3433	0.1149	4.18%

[a] In this scenario, SG yields are reduced to 2 dry tons per acre. It is assumed that expected decreased yields reduces fertilizer nutrients requirements as less tonnage is expected to be removed per acre than under the baseline scenario assumptions.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E27. Sensitivity Scenario 3A (Maximum-expected SG Yield is Set at 2 Dry Tons per Acre) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	232,917	sq ft	$107,142	%28,849	0.18%
Office Space	9,309	sq ft	1,396,350	245,361	1.54%
Pole Barns	83,646	sq ft	1,171,044	205,771	1.29%
Inside Machinery Storage	27,973	sq ft	3,356,760	589,837	3.69%
Headquarters Land	241,856	sq ft	27,572	2,412	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	4.35%
Tractor Size 2	39	#	5,149,950	840,707	5.27%
Tractor Size 3	0	#	0	0	0.00%
Planter	8	#	527,072	301,789	1.89%
Harvester	13	#	4,804,974	1,184,676	7.42%
In-Field Buggy	49	#	1,788,500	283,148	1.77%
Transport Trucks	114	#	12,084,000	1,954,776	12.25%
High-Energy Sorghum Trailers	114	#	5,916,600	672,136	4.21%
Switchgrass Trailers	17	#	595,000	74,166	0.46%
Support Vehicles	26	#	910,000	217,185	1.36%
Storage Handling	35	#	4,305,875	579,863	3.63%
Disc	9	#	404,966	112,008	0.70%
Bedder	10	#	199,000	21,352	0.13%
Fertilizer Toolbar	8	#	120,000	21,373	0.13%
Cultivator	3	#	283,500	67,084	0.42%
Sprayer	2	#	453,256	79,564	0.50%
Hay Cutter	8	#	926,904	218,034	1.37%
Wheel Rake	4	#	86,500	25,665	0.16%
Square Baler	9	#	872,721	149,034	0.93%
Hipper	9	#	215,145	38,319	0.24%
Rolling Cultivator	4	#	121,160	34,293	0.21%
Land Plane	8	#	316,000	84,854	0.53%
Bale Wagon	15	#	2,181,480	464,354	2.91%
Hay Squeeze	10	#	1,365,250	281,010	1.76%
Irrigation					
Develop Irrigation Well Size 2	86	#	22,722,275	1,834,057	11.49%
Re-Lift Pump	246	#	4,243,500	404,930	2.54%
SG Custom Establishment					
SG Harvest Production	56,222	acres	16,287,456	1,198,172	7.51%
SG Insurance Production	55,000	acres	15,933,500	1,172,134	7.34%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.19%
Purchase Storage	149	#	15,883,400	1,459,352	9.14%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.46%
Total Cost			$130,486,279	$15,963,162	100%

Table E28. Sensitivity Scenario 3A (Maximum-expected SG Yield is Set at 2 Dry Tons per Acre) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$1,002,484	2.49%
Land				
HES Land	acres	36,864	2,119,680	5.26%
SG Production Land	acres	56,222	1,264,995	3.14%
SG Insurance Land	acres	55,000	962,500	2.39%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	20.64%
Hire Part-Time Labor	hours	40,305	543,777	1.35%
Irrigation				
Pump Groundwater	acre-inches	614,523	3,440,157	8.54%
HES Field Operations				
Disc	n/a	n/a	129,510	0.32%
Disc	n/a	n/a	129,510	0.32%
Land Plane	n/a	n/a	216,463	0.54%
Bed	n/a	n/a	68,524	0.17%
Hip Beds	n/a	n/a	70,922	0.18%
Fertilize	n/a	n/a	6,989,739	17.34%
Hip Beds	n/a	n/a	70,922	0.18%
Spray	n/a	n/a	441,477	1.10%
Condition Beds	n/a	n/a	73,247	0.18%
Always Planting	n/a	n/a	1,470,338	3.65%
Cultivate	n/a	n/a	82,032	0.20%
Always Harvesting	n/a	n/a	1,983,382	4.92%
Support Vehicles	n/a	n/a	24,897	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	4,244,234	10.53%
Transportation				
Transport HES	wet ton	954,472	2,264,600	5.62%
Transport SG	dry tons	100,000	353,171	0.88%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	5,637	56,548	0.14%
Transfer Tractor Hours 152 hp to 100 hp	hours	14,709	100,834	0.25%
Overhead Management				
Overhead Management	persons	46	3,876,855	9.62%
Total Cost			40,298,501	100.00%

Table E29. Summary of Sensitivity Scenario 3A (Maximum-Expected SG Yield is Set at 2 Dry Tons per Acre), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$15,963,162	$171.49	$39.91	$0.5321	28.37%
Annual Operating Costs	40,298,501	432.92	100.75	1.3433	71.63%
Total Cost	$56,261,663	$604.41	$140.65	$1.8754	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E30. Critical Results for Sensitivity Scenario 3B (Maximum-expected SG Yield is Set at 6 Dry Tons per Acre), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 3B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,858	13	0.04%
Acres of SG	37,225	18,784	(18,441)	(49.54%)
Total farm acres[d]	187,760	$147,858	(39,902)	(21.25%)
HES Dry Ton Production	313,266	313,405	139	0.04%
HES Wet Ton Production	950,719	950,094	(625)	(0.07%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.50	0.00	0.04%
Average SG Dry Ton Yield per Acre	2.69	5.32	2.63	97.91%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$50,722,411	($2,879,792)	(5.37%)
Cost per Acre of All Biomass feedstock Produced	723.67	911.58	187.91	25.97%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	126.81	(7.20)	(5.38%)
Cost per Gallon of Fuel	1.7867	1.6907	(0.0960)	(5.37%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$105,249,163	($13,000,132)	(10.99%)
Annualized Investment Costs	14,919,357	13,716,680	(1,202,677)	(8.06%)
Percent of All Costs	27.8%	27.0%	(0.8%)	--
Cost per Acre of All Biomass feedstock Produced	$201.42	246.52	45.10	22.39%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	34.29	(3.01)	(8.07%)
Cost per Gallon of Fuel	0.4973	0.4572	(0.0401)	(8.06%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$37,005,730	($1,677,115)	(4.34%)
Percent of All Costs	72.2%	73.0%	0.8%	--
Cost per Acre of All Biomass feedstock Produced	522.25	665.07	142.82	27.35%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	92.51	(4.20)	(4.34%)
Cost per Gallon of Fuel	1.2894	1.2335	0.0051	(4.34%)

[a] In this scenario, SG yields are increased to 6 dry tons per acre. It is assumed that expected increased yields increase fertilizer nutrients requirements as more tonnage is expected to be removed per acre than under the baseline scenario assumptions.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E31. Sensitivity Scenario 3B (Maximum-expected SG Yield is Set at 6 Dry Tons per Acre) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	224,493	sq ft	$103,267	$27,806	0.20%
Office Space	5,565	sq ft	834,750	146,679	1.07%
Pole Barns	85,225	sq ft	1,193,150	209,656	1.53%
Inside Machinery Storage	24,239	sq ft	2,908,680	511,102	3.73%
Headquarters Land	230,058	sq ft	26,227	2,294	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	5.06%
Tractor Size 2	38	#	5,017,900	819,151	5.97%
Tractor Size 3	0	#	0	0	0.00%
Planter	7	#	461,188	264,065	1.93%
Harvester	13	#	4,804,974	1,184,676	8.64%
In-Field Buggy	49	#	1,788,500	283,148	2.06%
Transport Trucks	114	#	12,084,000	1,954,776	14.25%
High-Energy Sorghum Trailers	114	#	5,916,600	672,136	4.90%
Switchgrass Trailers	19	#	665,000	82,891	0.60%
Support Vehicles	26	#	910,000	217,185	1.58%
Storage Handling	35	#	4,305,875	579,863	4.23%
Disc	9	#	404,966	112,008	0.82%
Bedder	13	#	258,700	27,758	0.20%
Fertilizer Toolbar	8	#	120,000	21,373	0.16%
Cultivator	3	#	283,500	67,084	0.49%
Sprayer	1	#	226,628	39,782	0.29%
Hay Cutter	3	#	347,589	81,763	0.60%
Wheel Rake	2	#	43,250	12,832	0.09%
Square Baler	4	#	387,876	66,237	0.48%
Hipper	13	#	310,765	55,350	0.40%
Rolling Cultivator	4	#	121,160	34,293	0.25%
Land Plane	8	#	316,000	84,854	0.62%
Bale Wagon	11	#	1,599,752	340,526	2.48%
Hay Squeeze	11	#	1,501,775	309,111	2.25%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	12.13%
Re-Lift Pump	246	#	4,243,500	404,930	2.95%
SG Custom Establishment					
SG Harvest Production	18,784	acres	6,087,804	447,844	3.26%
SG Insurance Production	18,500	acres	5,995,850	441,079	3.22%
Storage					
Storage Land	6,021,120	sq ft	1,204,224	187,517	1.37%
Purchase Storage	147	#	15,670,200	1,439,763	10.50%
Silo Cover	3,492,720	sq ft	873,180	229,894	1.68%
Total Cost			$105,249,163	$13,716,680	100.00%

Table E32. Sensitivity Scenario 3B (Maximum-expected SG Yield is Set at 6 Dry Tons per Acre) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$920,541	2.49%
Land				
HES Land	acres	36,858	2,119,335	5.73%
SG Production Land	acres	18,784	422,640	1.14%
SG Insurance Land	acres	18,500	323,750	0.87%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	22.48%
Hire Part-Time Labor	hours	40,279	543,428	1.47%
Irrigation				
Pump Groundwater	acre-inches	614,423	3,439,596	9.29%
HES Field Operations				
Disc	n/a	n/a	129,489	0.35%
Disc	n/a	n/a	129,489	0.35%
Land Plane	n/a	n/a	216,428	0.58%
Bed	n/a	n/a	68,513	0.19%
Hip Beds	n/a	n/a	70,910	0.19%
Fertilize	n/a	n/a	6,988,601	18.89%
Hip Beds	n/a	n/a	70,910	0.19%
Spray	n/a	n/a	441,405	1.19%
Condition Beds	n/a	n/a	73,235	0.20%
Always Planting	n/a	n/a	1,470,099	3.97%
Cultivate	n/a	n/a	82,018	0.22%
Always Harvesting	n/a	n/a	1,979,413	5.35%
Support Vehicles	n/a	n/a	24,893	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	2,589,334	7.00%
Transportation				
Transport HES	wet ton	950,094	2,254,506	6.09%
Transport SG	dry tons	100,000	353,171	0.95%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	6,558	65,780	0.18%
Transfer Tractor Hours 152 hp to 100 hp	hours	4,914	33,689	0.09%
Overhead Management				
Overhead Management	persons	46	3,876,855	10.48%
Total cost			$37,005,730	100.00%

Table E33. Summary of Sensitivity Scenario 3B (Maximum-expected SG Yield is Set at 6 Dry Tons per Acre), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$13,716,680	$246.52	$34.29	$0.4572	27.04%
Annual Operating Costs	37,005,730	665.07	92.51	1.2335	72.96%
Total Cost	$50,722,411	$911.58	$126.81	$1.6907	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E34. Critical Results for Sensitivity Scenario 4A (HES Only), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 4A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	50,515	13,670	37.10%
Acres of SG	37,225	0	(37,225)	(100.00%)
Total farm acres[d]	187,760	191,545	3,785	2.02
HES Dry Ton Production	313,266	429,844	116,578	37.21%
HES Wet Ton Production	950,719	1,301,093	350,374	36.85%
SG Dry Ton Production	100,000	0	(100,000)	(100.00%)
Average HES Dry Ton Yield per Acre	8.50	8.51	0.01	0.11%
Average SG Dry Ton Yield per Acre	2.69	0	(2.69)	(100.00%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$63,679,880	$10,077,677	18.80%
Cost per Acre of All Biomass feedstock Produced	723.67	1,260.61	536.94	74.20%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	159.20	25.19	18.80%
Cost per Gallon of Fuel	1.7867	2.1227	0.3360	18.80%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$137,706,009	$19,456,714	16.45%
Annualized Investment Costs	14,919,357	17,653,893	2,734,536	18.33%
Percent of All Costs	27.8%	27.6%	(0.2%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	349.48	148.06	73.51%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	44.13	6.83	18.32%
Cost per Gallon of Fuel	0.4973	0.5885	0.0912	18.33%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$46,025,987	$7,343,142	18.98%
Percent of All Costs	72.2%	72.4%	(0.2%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	911.14	388.89	74.46%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	115.06	18.35	18.98%
Cost per Gallon of Fuel	1.2894	1.5342	0.2448	18.99%

[a] In this scenario, HES is the only biomass feedstock produced and supplied to the conversion facility. The maintenance of SG insurance acreage for 25% of the conversion facility's annual biomass feedstock requirements is included, however.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E35. Sensitivity Scenario 4A (HES Only) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	274,118	sq ft	$ 126,094	$ 33,953	0.19%
Office Space	5,052	sq ft	757,800	133,158	0.75%
Pole Barns	103,429	sq ft	1,448,006	254,438	1.44%
Inside Machinery Storage	31,104	sq ft	3,732,480	655,857	3.72%
Headquarters Land	279,170	sq ft	31,825	2,784	0.02%
Purchased Machinery					
Tractor Size 1	26	#	4,486,560	858,999	4.87%
Tractor Size 2	57	#	7,526,850	1,228,726	6.96%
Planter	9	#	592,956	339,513	1.92%
Harvester	18	#	6,653,040	1,640,320	9.29%
In-Field Buggy	67	#	2,445,500	387,161	2.19%
Transport Trucks	157	#	16,642,000	2,692,104	15.25%
High-Energy Sorghum Trailers	157	#	8,148,300	925,661	5.24%
Switchgrass Trailers	0	#	0.00	0.00	0.00%
Support Vehicles	36	#	1,260,000	300,718	1.70%
Storage Handling	49	#	6,028,225	811,808	4.60%
Disc	13	#	584,950	161,790	0.92%
Bedder	15	#	298,500	32,028	0.18%
Fertilizer Toolbar	11	#	165,000	29,388	0.17%
Cultivator	3	#	283,500	67,084	0.38%
Sprayer	2	#	453,256	79,564	0.45%
Hay Cutter	0	#	0.00	0.00	0.00%
Wheel Rake	0	#	0.00	0.00	0.00%
Square Baler	0	#	0.00	0.00	0.00%
Hipper	15	#	358,575	63,865	0.36%
Rolling Cultivator	5	#	151,450	42,866	0.24%
Land Plane	11	#	434,500	116,674	0.66%
Bale Wagon	0	#	0.00	0.00	0.00%
Hay Squeeze	0	#	0.00	0.00	0.00%
Irrigation					
Develop Irrigation Well Size 2	101	#	26,685,463	2,153,950	12.20%
Re-Lift Pump	337	#	5,813,250	554,721	3.14%
SG Custom Establishment					
SG Harvest Production	0	acres	0.00	0.00	0.00%
SG Insurance Production	40,000	acres	11,932,000	877,767	4.97%
Storage					
Storage Land	10,403,840	sq ft	2,080,768	324,009	1.84%
Purchase Storage	254	#	27,076,400	2,487,754	14.09%
Silo Cover	6,035,040	sq ft	1,508,760	397,233	2.25%
Total Cost			$137,706,009	$17,653,893	100.00%

Table E36. Sensitivity Scenario 4A (HES Only) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 1,145,017	2.49%
Land				
HES Land	acres	50,515	2,904,613	6.31%
SG Production Land	acres	0	0.00	0.00%
SG Insurance Land	acres	40,000	700,000	1.52%
Labor				
Hire Full-Time Labor	persons	250	12,231,875	26.58%
Hire Part-Time Labor	hours	39,659	535,055	1.16%
Irrigation				
Pump Groundwater	acre-inches	842,080	4,714,044	10.24%
HES Field Operations				
Disc	n/a	n/a	177,467	0.39%
Disc	n/a	n/a	177,467	0.39%
Land Plane	n/a	n/a	296,619	0.64%
Bed	n/a	n/a	93,898	0.20%
Hip Beds	n/a	n/a	97,184	0.21%
Fertilize	n/a	n/a	9,578,034	20.81%
Hip Beds	n/a	n/a	97,184	0.21%
Spray	n/a	n/a	604,956	1.31%
Condition Beds	n/a	n/a	100,371	0.22%
Always Planting	n/a	n/a	2,014,803	4.38%
Cultivate	n/a	n/a	112,408	0.24%
Always Harvesting	n/a	n/a	2,711,938	5.89%
Support Vehicles	n/a	n/a	34,116	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	0.00	0.00%
Transportation				
Transport HES	wet tons	1,301,093	3,082,845	6.70%
Transport SG	dry tons	0	0.00	0.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	5,325	53,419	0.12%
Transfer Tractor Hours 152 hp to 100 hp	hours	0	0.00	0.00%
Overhead Management				
Overhead Management	persons	54	4,562,635	9.91%
Total cost			$46,025,987	100.00%

Table E37. Summary of Sensitivity Scenario 4A (HES Only), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$17,653,893	$ 349.48	$ 44.13	$0.5885	27.72%
Annual Operating Costs	46,025,987	911.14	115.06	1.5342	72.28%
Total Cost	$63,679,880	$1,260.61	$159.20	$2.1227	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E38. Critical Results for Sensitivity Scenario 4B (SG Only), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 4B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	0	(36,845)	(100.00%)
Acres of SG	37,225	145,743	108,518	291.52%
Total farm acres[d]	187,760	185,743	(2,017)	(1.07%)
HES Dry Ton Production	313,266	0	(313,266)	(100.00%)
HES Wet Ton Production	950,719	0	(950,719)	(100.00%)
SG Dry Ton Production	100,000	403,139	303,139	303.14%
Average HES Dry Ton Yield per Acre	8.50	0.00	(8.50)	(100.00%)
Average SG Dry Ton Yield per Acre	2.69	2.77	0.08	2.83%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$35,284,151	($18,318,052)	(34.17%)
Cost per Acre of All Biomass feedstock Produced	723.67	242.10	(481.57)	(66.55%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	88.21	(45.80)	(34.18%)
Cost per Gallon of Fuel	1.7867	1.1761	(0.6106)	(34.17%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$81,678,658	($36,570,637)	(30.93%)
Annualized Investment Costs	14,919,357	8,455,084	(6,464,273)	(43.33%)
Percent of All Costs	27.8%	24.0%	(3.8%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	58.01	(143.41)	(71.20%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	21.14	(16.16)	(43.33%)
Cost per Gallon of Fuel	0.4973	0.2818	(0.2155)	(43.33%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$26,829,067	($11,853,778)	(30.64%)
Percent of All Costs	72.2%	76.0%	3.8%	--
Cost per Acre of All Biomass feedstock Produced	522.25	184.08	(338.17)	(64.75%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	67.07	(29.64)	(30.65%)
Cost per Gallon of Fuel	1.2894	0.8943	(0.3951)	(30.64%)

[a] In this scenario, SG is the only biomass feedstock produced and supplied to the conversion facility. The maintenance of SG insurance acreage for 25% of the conversion facility's annual biomass feedstock requirements is included.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E39. Sensitivity Scenario 4B (SG Only) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	81,749	sq ft	$ 37,605	$ 10,126	0.12%
Office Space	14,575	sq ft	2,186,250	384,160	4.54%
Pole Barns	24,310	sq ft	340,340	59,803	0.71%
Inside Machinery Storage	9,277	sq ft	1,113,240	195,614	2.31%
Headquarters Land	96,324	sq ft	10,981	961	0.01%
Purchased Machinery					
Tractor Size 1	1	#	172,560	33,038	0.39%
Tractor Size 2	0	#	0.00	0.00	0.00%
Tractor Size 3	17	#	1,161,066	250,751	2.97%
Planter	0	#	0.00	0.00	0.00%
Harvester	0	#	0.00	0.00	0.00%
In-Field Buggy	0	#	0.00	0.00	0.00%
Transport Trucks	35	#	3,710,000	600,151	7.10%
High-Energy Sorghum Trailers	0	#	0.00	0.00	0.00%
Switchgrass Trailers	35	#	1,225,000	152,694	1.81%
Support Vehicles	0	#	0.00	0.00	0.00%
Storage Handling	0	#	0.00	0.00	0.00%
Disc	0	#	0.00	0.00	0.00%
Bedder	0	#	0.00	0.00	0.00%
Fertilizer Toolbar	0	#	0.00	0.00	0.00%
Cultivator	0	#	0.00	0.00	0.00%
Sprayer	2	#	453,256	79,564	0.94%
Hay Cutter	10	#	1,158,630	272,542	3.22%
Wheel Rake	6	#	129,750	38,497	0.46%
Square Baler	12	#	1,163,628	198,712	2.35%
Hipper	0	#	0.00	0.00	0.00%
Rolling Cultivator	0	#	0.00	0.00	0.00%
Land Plane	0	#	0.00	0.00	0.00%
Bale Wagon	26	#	3,781,232	804,881	9.52%
Hay Squeeze	21	#	2,867,025	590,121	6.98%
Irrigation					
Develop Irrigation Well Size 2	0	#	0.00	0.00	0.00%
Re-Lift Pump	0	#	0.00	0.00	0.00%
SG Custom Establishment					
SG Harvest Production	145,743	acres	43,475,103	3,198,208	37.83%
SG Insurance Production	40,000	acres	11,932,000	877,767	10.38%
Storage					
Storage Land	2,293,760	sq ft	458,752	71,435	0.84%
Purchase Storage	56	#	5,969,600	548,481	6.49%
Silo Cover	1,330,560	sq ft	332,640	87,579	1.04%
Total Cost			$81,678,658	$8,455,084	100.00%

Table B40. Sensitivity Scenario 4B (SG Only) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 667,288	2.49%
Land				
HES Land	acres	0	0.00	0.00%
SG Production Land	acres	145,743	3,279,218	12.22%
SG Insurance Land	acres	40,000	700,000	2.61%
Labor				
Hire Full-Time Labor	persons	80	3,914,200	14.59%
Hire Part-Time Labor	hours	25,887	349,253	1.30%
Irrigation				
Pump Groundwater	acre-inches	0	0.00	0.00%
HES Field Operations				
Disc	n/a	n/a	0.00	0.00%
Disc	n/a	n/a	0.00	0.00%
Land Plane	n/a	n/a	0.00	0.00%
Bed	n/a	n/a	0.00	0.00%
Hip Beds	n/a	n/a	0.00	0.00%
Fertilize	n/a	n/a	0.00	0.00%
Hip Beds	n/a	n/a	0.00	0.00%
Spray	n/a	n/a	0.00	0.00%
Condition Beds	n/a	n/a	0.00	0.00%
Always Planting	n/a	n/a	0.00	0.00%
Cultivate	n/a	n/a	0.00	0.00%
Always Harvesting	n/a	n/a	0.00	0.00%
Support Vehicles	n/a	n/a	0.00	0.00%
SG Field Operations				
Grow and Harvest	n/a	n/a	13,371,563	49.84%
Transportation				
Transport HES	wet tons	0	0.00	0.06%
Transport SG	dry tons	403,139	1,438,772	5.31%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	203	2,032	0.01%
Transfer Tractor Hours 152 hp to 100 hp	hours	203	1,389	0.01%
Overhead Management				
Overhead Management	persons	37	3,105,352	11.57%
Total cost			$26,829,067	100.00%

Table B41. Summary of Sensitivity Scenario 4B (SG Only), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$ 8,455,084	$ 58.01	$21.14	$0.2818	23.96%
Annual Operating Costs	26,829,067	184.08	67.07	0.8943	76.04%
Total Cost	$35,284,151	$242.10	$88.21	$1.1761	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E42. Critical Results for Sensitivity Scenario 5A (Reduce Capital Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,611	(234)	(0.64%)
Acres of SG	37,225	37,251	26	(0.07%)
Total farm acres[d]	187,760	187,084	(676)	(0.36%)
HES Dry Ton Production	313,266	313,044	(222)	(0.07%)
HES Wet Ton Production	950,719	947,497	(3,222)	(0.34%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.55	0.05	0.59%
Average SG Dry Ton Yield per Acre	2.69	2.68	(0.01)	(0.20%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	51,346,597	($2,255,606)	(4.21%)
Cost per Acre of All Biomass feedstock Produced	723.67	695.17	(28.50)	(3.94%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	128.37	(5.64)	(4.21%)
Cost per Gallon of Fuel	1.7867	1.7116	(0.0751)	(4.21%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$101,248,526	($17,000,769)	(14.38%)
Annualized Investment Costs	14,919,357	12,788,690	(2,130,667)	(14.28%)
Percent of All Costs	27.8%	75.09%	(2.9%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	173.14	(28.28)	(14.04%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	31.97	(5.33)	(14.28%)
Cost per Gallon of Fuel	0.4973	0.4263	(0.0710)	(14.28%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$38,557,907	($124,938)	(0.32%)
Percent of All Costs	72.2%	75.09%	2.9%	--
Cost per Acre of All Biomass feedstock Produced	522.25	522.03	(0.22)	(0.04%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	96.39	(0.32)	(0.33%)
Cost per Gallon of Fuel	1.2894	1.2853	(0.0041)	(0.32%)

[a] In this scenario, capital costs are reduced by 15 percent.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E43. Sensitivity Scenario 5A (Reduce Capital Costs by 15%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	238,921	sq ft	$ 93,418	$ 25,154	0.20%
Office Space	7,387	sq ft	941,843	165,497	1.29%
Pole Barns	89,228	sq ft	1,061,813	186,578	1.46%
Inside Machinery Storage	26,539	sq ft	2,706,978	475,660	3.72%
Headquarters Land	246,308	sq ft	23,867	2,088	0.02%
Purchased Machinery					
Tractor Size 1	22	#	3,226,872	617,818	4.83%
Tractor Size 2	39	#	4,377,458	714,601	5.59%
Planter	7	#	392,010	224,456	1.76%
Harvester	13	#	4,084,228	1,006,974	7.87%
In-Field Buggy	49	#	1,520,225	240,676	1.88%
Transport Trucks	115	#	10,361,500	1,676,135	13.11%
High-Energy Sorghum Trailers	115	#	5,073,225	576,327	4.51%
Switchgrass Trailers	20	#	595,000	74,166	0.58%
Support Vehicles	26	#	773,500	184,607	1.44%
Storage Handling	36	#	3,764,565	506,966	3.96%
Disc	8	#	305,974	84,628	0.66%
Bedder	14	#	236,810	25,409	0.20%
Fertilizer Toolbar	8	#	102,000	18,167	0.14%
Cultivator	3	#	240,975	57,021	0.45%
Sprayer	1	#	192,634	33,815	0.26%
Hay Cutter	6	#	590,901	138,996	1.09%
Wheel Rake	4	#	73,525	21,815	0.17%
Square Baler	8	#	659,389	112,603	0.88%
Hipper	14	#	284,470	50,667	0.40%
Rolling Cultivator	4	#	102,986	29,149	0.23%
Land Plane	9	#	302,175	81,142	0.63%
Bale Wagon	15	#	1,854,258	394,701	3.09%
Hay Squeeze	12	#	1,392,555	286,630	2.24%
Irrigation					
Develop Irrigation Well Size 2	78	#	17,517,289	1,413,930	11.06%
Re-Lift Pump	245	#	3,592,313	342,791	2.68%
SG Custom Establishment					
SG Harvest Production	37,251	acres	9,445,132	694,823	5.43%
SG Insurance Production	40,000	acres	10,142,200	746,102	5.83%
Storage					
Storage Land	6,021,120	sq ft	1,023,590	159,390	1.25%
Purchase Storage	147	#	13,319,670	1,223,799	9.57%
Silo Cover	3,492,720	sq ft	873,180	195,410	1.53%
Total Cost			$101,248,526	$12,788,690	100.00%

Table E44. Sensitivity Scenario 5A (Reduce Capital Costs by 15%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 959,168	2.49%
Land				
HES Land	acres	36,611	2,105,133	5.46%
SG Production Land	acres	37,251	838,148	2.17%
SG Insurance Land	acres	40,000	700,000	1.82%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.57%
Hire Part-Time Labor	hours	40,719	549,363	1.42%
Irrigation				
Pump Groundwater	acre-inches	610,289	3,416,456	8.86%
HES Field Operations				
Disc	n/a	n/a	128,618	0.33%
Disc	n/a	n/a	128,618	0.33%
Land Plane	n/a	n/a	214,972	0.56%
Bed	n/a	n/a	68,052	0.18%
Hip Beds	n/a	n/a	70,433	0.18%
Fertilize	n/a	n/a	6,941,585	18.00%
Hip Beds	n/a	n/a	70,433	0.18%
Spray	n/a	n/a	438,436	1.14%
Condition Beds	n/a	n/a	72,743	0.19%
Always Planting	n/a	n/a	1,460,209	3.79%
Cultivate	n/a	n/a	81,467	0.21%
Always Harvesting	n/a	n/a	1,969,373	5.11%
Support Vehicles	n/a	n/a	24,725	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,397,326	8.81%
Transportation				
Transport HES	wet tons	947,497	2,249,104	5.83%
Transport SG	dry tons	100,000	353,171	0.92%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	5,883	59,009	0.15%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,746	66,810	0.17%
Overhead Management				
Overhead Management	persons	46	3,876,855	10.05%
Total cost			$38,557,907	100.00%

Table E45. Summary of Sensitivity Scenario 5A (Reduce Capital Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$12,788,690	$173.14	$ 31.97	$0.426	24.91%
Annual Operating Costs	38,557,907	522.03	96.39	1.285	75.09%
Total Cost	$51,346,597	$695.17	$128.37	$1.712	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E46. Critical Results for Sensitivity Scenario 5B (Increase Capital Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,845	0	0.00%
Acres of SG	37,225	37,225	0	0.00%
Total farm acres[d]	187,760	187,760	0	0.00%
HES Dry Ton Production	313,266	313,266	0	0.00%
HES Wet Ton Production	950,719	950,719	0	0.00%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.50	0.00	0.03%
Average SG Dry Ton Yield per Acre	2.69	2.69	0.00	0.00%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$55,825,551	$2,223,348	4.15%
Cost per Acre of All Biomass feedstock Produced	723.67	753.69	30.02	4.15%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	139.56	5.55	4.14%
Cost per Gallon of Fuel	1.7867	1.8609	0.0742	4.15%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$135,716,771	$17,467,476	14.77%
Annualized Investment Costs	14,919,357	17,142,705	2,223,348	14.90%
Percent of All Costs	27.8%	30.7%	2.9%	--
Cost per Acre of All Biomass feedstock Produced	201.42	231.44	30.02	14.90%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	42.86	5.56	14.90%
Cost per Gallon of Fuel	0.4973	0.5714	0.0741	14.91%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$38,682,845	$ 0	0.00%
Percent of All Costs	72.2%	69.29%	(2.9%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	522.25	0.00	0.00%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	96.71	0.00	0.00%
Cost per Gallon of Fuel	1.2894	1.2894	0.0000	0.00%

[a] In this scenario, capital costs are increased by 15 percent.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E47. Sensitivity Scenario 5B (Increase Capital Costs by 15%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	233,881	sq ft	$ 123,723	$ 33,314	0.19%
Office Space	7,407	sq ft	1,277,708	224,514	1.31%
Pole Barns	87,315	sq ft	1,405,772	247,017	1.44%
Inside Machinery Storage	25,922	sq ft	3,577,236	628,578	3.67%
Headquarters Land	241,288	sq ft	31,633	2,767	0.02%
Purchased Machinery					
Tractor Size 1	21	#	4,167,324	797,878	4.65%
Tractor Size 2	37	#	5,618,728	917,233	5.35%
Planter	7	#	530,366	303,675	1.77%
Harvester	13	#	5,525,720	1,362,377	7.95%
In-Field Buggy	49	#	2,056,775	325,620	1.90%
Transport Trucks	115	#	14,018,500	2,267,712	13.23%
High-Energy Sorghum Trailers	115	#	6,863,775	779,737	4.55%
Switchgrass Trailers	20	#	805,000	100,342	0.59%
Support Vehicles	26	#	1,046,500	249,763	1.46%
Storage Handling	34	#	4,810,278	647,789	3.78%
Disc	8	#	413,965	114,497	0.67%
Bedder	13	#	297,505	31,921	0.19%
Fertilizer Toolbar	8	#	138,000	24,579	0.14%
Cultivator	3	#	326,025	77,146	0.45%
Sprayer	1	#	260,622	45,750	0.27%
Hay Cutter	6	#	799,455	188,054	1.10%
Wheel Rake	4	#	$99,475	29,515	0.17%
Square Baler	8	#	892,115	152,346	0.89%
Hipper	14	#	384,871	68,549	0.40%
Rolling Cultivator	4	#	139,334	39,437	0.23%
Land Plane	8	#	363,400	97,582	0.57%
Bale Wagon	15	#	2,508,702	534,007	3.12%
Hay Squeeze	12	#	1,884,045	387,794	2.26%
Irrigation					
Develop Irrigation Well Size 2	78	#	23,699,861	1,912,964	11.16%
Re-Lift Pump	246	#	4,880,025	465,669	2.72%
SG Custom Establishment					
SG Harvest Production	37,225	acres	12,769,769	939,397	5.48%
SG Insurance Production	40,000	acres	13,721,800	1,009,432	5.89%
Storage					
Storage Land	6,021,120	sq ft	1,384,858	215,645	1.26%
Purchase Storage	147	#	18,020,730	1,655,728	9.66%
Silo Cover	3,492,720	sq ft	873,180	264,379	1.54%
Total Cost			$135,716,771	$17,142,705	100.00%

Table E48. Sensitivity Scenario 5B (Increase Capital Costs by 15%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 962,278	2.49%
Land				
HES Land	acres	36,845	2,118,588	5.48%
SG Production Land	acres	37,225	837,563	2.17%
SG Insurance Land	acres	40,000	700,000	1.81%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.50%
Hire Part-Time Labor	hours	40,356	544,461	1.41%
Irrigation				
Pump Groundwater	acre-inches	614,199	3,438,341	8.89%
HES Field Operations				
Disc	n/a	n/a	129,441	0.33%
Disc	n/a	n/a	129,441	0.33%
Land Plane	n/a	n/a	216,349	0.56%
Bed	n/a	n/a	68,488	0.18%
Hip Beds	n/a	n/a	70,884	0.18%
Fertilize	n/a	n/a	6,986,051	18.06%
Hip Beds	n/a	n/a	70,884	0.18%
Spray	n/a	n/a	441,244	1.14%
Condition Beds	n/a	n/a	73,209	0.19%
Always Planting	n/a	n/a	1,469,562	3.80%
Cultivate	n/a	n/a	81,988	0.21%
Always Harvesting	n/a	n/a	1,979,530	5.12%
Support Vehicles	n/a	n/a	24,884	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,395,417	8.78%
Transportation				
Transport HES	wet tons	950,719	2,255,441	5.83%
Transport SG	dry tons	100,000	353,171	0.91%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,408	74,309	0.19%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,739	66,763	0.17%
Overhead Management				
Overhead Management	persons	46	3,876,855	10.02%
Total cost			$38,682,845	100.00%

Table E49. Summary of Sensitivity Scenario 5B (Increase Capital Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$17,142,705	$231.44	$ 42.86	$0.5714	30.71%
Annual Operating Costs	38,682,845	522.25	96.71	1.2894	69.29%
Total Cost	$55,825,551	$753.69	$139.56	$1.8609	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E50 Critical Results for Sensitivity Scenario 5C (Reduce Operating Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5C[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	35,359	(1,486)	(4.03%)
Acres of SG	37,225	37,297	72	0.19%
Total farm acres[d]	187,760	183,374	(4,386)	(2.34%)
HES Dry Ton Production	313,266	314,325	1,059	0.34%
HES Wet Ton Production	950,719	954,272	3,533	0.37%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.89	0.39	4.58%
Average SG Dry Ton Yield per Acre	2.69	2.68	(0.01)	(0.33%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$48,271,306	($5,330,897)	(9.95%)
Cost per Acre of All Biomass feedstock Produced	723.67	664.38	(59.29)	(8.19%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	120.68	(13.33)	(9.95%)
Cost per Gallon of Fuel	1.7867	1.6090	(0.1777)	(9.94%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$123,405,798	$5,156,503	4.36%
Annualized Investment Costs	14,919,357	15,352,806	433,449	2.91%
Percent of All Costs	27.8%	31.8%	4.0%	--
Cost per Acre of All Biomass feedstock Produced	201.42	211.31	9.89	4.91%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	38.38	1.08	2.90%
Cost per Gallon of Fuel	0.4973	0.5118	0.0145	2.91%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$32,918,500	($5,764,345)	(14.90%)
Percent of All Costs	72.2%	68.2%	(4.0%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	453.07	(69.18)	(13.25%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	82.30	(14.41)	(14.90%)
Cost per Gallon of Fuel	1.2894	1.0973	(0.1921)	(14.90%)

[a] In this scenario, operating costs are reduced by 15 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E51. Sensitivity Scenario 5C (Reduce Operating Costs by 15%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	228,216	sq ft	$ 104,979	$ 28,267	0.18%
Office Space	7,266	sq ft	1,089,900	191,513	1.25%
Pole Barns	83,889	sq ft	1,174,446	206,369	1.34%
Inside Machinery Storage	26,443	sq ft	3,173,160	557,576	3.63%
Headquarters Land	235,196	sq ft	26,812	2,346	0.02%
Purchased Machinery					
Tractor Size 1	23	#	3,968,880	759,884	4.95%
Tractor Size 2	39	#	5,149,950	840,707	5.48%
Planter	8	#	527,072	301,789	1.97%
Harvester	12	#	4,435,360	1,093,547	7.12%
In-Field Buggy	50	#	1,825,000	288,926	1.88%
Transport Trucks	122	#	12,932,000	2,091,953	13.63%
High-Energy Sorghum Trailers	122	#	6,331,800	719,304	4.69%
Switchgrass Trailers	18	#	630,000	78,528	0.51%
Support Vehicles	25	#	875,000	208,832	1.36%
Storage Handling	36	#	4,428,900	596,430	3.88%
Disc	7	#	314,973	87,118	0.57%
Bedder	13	#	258,700	27,758	0.18%
Fertilizer Toolbar	7	#	105,000	18,701	0.12%
Cultivator	2	#	189,000	44,722	0.29%
Sprayer	1	#	226,628	39,782	0.26%
Hay Cutter	6	#	695,178	163,525	1.07%
Wheel Rake	3	#	64,875	19,249	0.13%
Square Baler	7	#	678,783	115,915	0.76%
Hipper	7	#	167,335	29,804	0.19%
Rolling Cultivator	5	#	151,450	42,866	0.28%
Land Plane	8	#	316,000	84,854	0.55%
Bale Wagon	13	#	1,890,616	402,440	2.62%
Hay Squeeze	11	#	1,501,775	309,111	2.01%
Irrigation					
Develop Irrigation Well Size 2	93	#	24,571,763	1,983,340	12.92%
Re-Lift Pump	236	#	4,071,000	388,469	2.53%
SG Custom Establishment					
SG Harvest Production	37,296	acres	11,125,467	818,435	5.33%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.72%
Storage					
Storage Land	6,266,880	sq ft	1,253,376	195,171	1.27%
Purchase Storage	153	#	16,309,800	1,498,529	9.76%
Silo Cover	3,635,280	sq ft	908,820	239,278	1.56%
Total Cost			$123,405,798	$15,352,806	100.00%

Table E52. Sensitivity Scenario 5C (Reduce Operating Costs by 15%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 818,828	2.49%
Land				
HES Land	acres	35,359	1,728,171	5.25%
SG Production Land	acres	37,297	713,305	2.17%
SG Insurance Land	acres	40,000	565,000	1.72%
Labor				
Hire Full-Time Labor	persons	180	7,485,908	22.74%
Hire Part-Time Labor	hours	37,140	425,914	1.29%
Irrigation				
Pump Groundwater	acre-inches	589,429	2,819,052	8.56%
HES Field Operations				
Disc	n/a	n/a	105,588	0.32%
Disc	n/a	n/a	105,588	0.32%
Land Plane	n/a	n/a	176,480	0.54%
Bed	n/a	n/a	55,867	0.17%
Hip Beds	n/a	n/a	57,822	0.18%
Fertilize	n/a	n/a	5,698,669	17.31%
Hip Beds	n/a	n/a	57,822	0.18%
Spray	n/a	n/a	359,932	1.09%
Condition Beds	n/a	n/a	59,718	0.18%
Always Planting	n/a	n/a	1,198,753	3.64%
Cultivate	n/a	n/a	66,880	0.20%
Always Harvesting	n/a	n/a	1,797,351	5.46%
Support Vehicles	n/a	n/a	20,298	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	2,890,554	8.78%
Transportation				
Transport HES	wet tons	954,272	1,925,986	5.85%
Transport SG	dry tons	100,000	300,196	0.91%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,007	59,743	0.18%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,758	56,857	0.17%
Overhead Management				
Overhead Management	persons	47	3,368,191	10.23%
Total cost			$32,918,500	100.00%

Table E53. Summary of Sensitivity Scenario 5C (Reduce Operating Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$15,352,806	$211.31	$ 38.38	$0.5118	31.81%
Annual Operating Costs	32,918,500	453.07	82.30	1.0973	68.19%
Total Cost	$48,271,306	$664.38	$120.68	$1.6090	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E54. Critical Results for Sensitivity Scenario 5D (Increase Operating Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5D[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,883	38	0.10%
Acres of SG	37,225	37,180	(45)	(0.12%)
Total farm acres[d]	187,760	187,829	69	0.04%
HES Dry Ton Production	313,266	313,510	244	0.08%
HES Wet Ton Production	950,719	951,528	809	0.09%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.50	0.00	0.00%
Average SG Dry Ton Yield per Acre	2.69	2.29	0.00	0.00%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$59,269,781	$5,667,578	10.57%
Cost per Acre of All Biomass feedstock Produced	723.67	800.26	76.59	10.58%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	148.17	14.26	10.57%
Cost per Gallon of Fuel	1.7867	1.9757	0.1890	10.58%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$118,247,527	($1,768)	(0.00%)
Annualized Investment Costs	14,919,357	14,910,182	(9,175)	(0.06%)
Percent of All Costs	27.8%	25.2%	(2.6%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	201.32	(0.10)	(0.05%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	37.28	(0.02)	(0.07%)
Cost per Gallon of Fuel	0.4973	0.4970	(0.0003)	(0.06%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$44,359,599	$5,676,754	14.68%
Percent of All Costs	72.2%	74.8%	2.6%	--
Cost per Acre of All Biomass feedstock Produced	522.25	598.94	76.69	14.69%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	110.90	14.19	14.67%
Cost per Gallon of Fuel	1.2894	1.4787	0.1893	14.68%

[a] In this scenario, operating costs are increased by 15 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E55. Sensitivity Scenario 5D (Increase Operating Costs by 15%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	233,157	sq ft	$ 107,252	$ 28,879	0.19%
Office Space	7,407	sq ft	1,111,050	195,230	1.31%
Pole Barns	86,871	sq ft	1,216,194	213,705	1.43%
Inside Machinery Storage	25,677	sq ft	3,081,240	541,424	3.63%
Headquarters Land	240,564	sq ft	27,424	2,399	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	4.65%
Tractor Size 2	37	#	4,885,850	797,594	5.35%
Planter	7	#	461,188	264,065	1.77%
Harvester	13	#	4,804,974	1,184,676	7.95%
In-Field Buggy	49	#	1,788,500	283,148	1.90%
Transport Trucks	115	#	12,190,000	1,971,923	13.23%
High-Energy Sorghum Trailers	115	#	5,968,500	678,032	4.55%
Switchgrass Trailers	20	#	700,000	87,254	0.59%
Support Vehicles	26	#	910,000	217,185	1.46%
Storage Handling	34	#	4,182,850	563,295	3.78%
Disc	9	#	404,966	112,008	0.75%
Bedder	12	#	238,800	25,622	0.17%
Fertilizer Toolbar	8	#	120,000	21,373	0.14%
Cultivator	3	#	283,500	67,084	0.45%
Sprayer	1	#	226,628	39,782	0.27%
Hay Cutter	6	#	695,178	163,525	1.10%
Wheel Rake	4	#	86,500	25,665	0.17%
Square Baler	7	#	678,783	115,915	0.78%
Hipper	13	#	310,765	55,350	0.37%
Rolling Cultivator	4	#	121,160	34,293	0.23%
Land Plane	8	#	316,000	84,854	0.57%
Bale Wagon	15	#	2,181,480	464,354	3.11%
Hay Squeeze	12	#	1,638,300	337,212	2.26%
Irrigation					
Develop Irrigation Well Size 2	79	#	20,872,788	1,684,773	11.30%
Re-Lift Pump	246	#	4,243,500	404,930	2.72%
SG Custom Establishment					
SG Harvest Production	37,180	acres	11,090,794	815,884	5.47%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.89%
Storage					
Storage Land	6,021,120	sq ft	1,204,224	187,517	1.26%
Purchase Storage	147	#	15,670,200	1,439,763	9.66%
Silo Cover	3,492,720	sq ft	873,180	229,894	1.54%
Total Cost			$118,247,527	$14,910,182	100.00%

Table E56. Sensitivity Scenario 5D (Increase Operating Costs by 15%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 1,103,548	2.49%
Land				
HES Land	acres	36,883	2,438,888	5.50%
SG Production Land	acres	37,180	962,033	2.17%
SG Insurance Land	acres	40,000	835,000	1.88%
Labor				
Hire Full-Time Labor	persons	170	9,565,326	21.56%
Hire Part-Time Labor	hours	40,360	626,187	1.41%
Irrigation				
Pump Groundwater	acre-inches	614,837	3,943,259	8.89%
HES Field Operations				
Disc	n/a	n/a	149,012	0.34%
Disc	n/a	n/a	149,012	0.34%
Land Plane	n/a	n/a	249,060	0.56%
Bed	n/a	n/a	78,843	0.18%
Hip Beds	n/a	n/a	81,602	0.18%
Fertilize	n/a	n/a	8,042,308	18.13%
Hip Beds	n/a	n/a	81,602	0.18%
Spray	n/a	n/a	507,958	1.15%
Condition Beds	n/a	n/a	84,277	0.19%
Always Planting	n/a	n/a	1,691,753	3.81%
Cultivate	n/a	n/a	94,385	0.21%
Always Harvesting	n/a	n/a	2,125,927	4.79%
Support Vehicles	n/a	n/a	28,646	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,900,960	8.79%
Transportation				
Transport HES	wet tons	951,528	2,593,661	5.85%
Transport SG	dry tons	100,000	406,147	0.92%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,378	85,109	0.19%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,727	76,685	0.17%
Overhead Management				
Overhead Management	persons	46	4,458,383	10.05%
Total cost			$44,359,599	100.00%

Table E57. Summary of Sensitivity Scenario 5D (Increase Operating Costs by 15%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$14,910,182	$201.32	$37.28	$0.4970	25.16%
Annual Operating Costs	44,359,599	598.94	110.90	$.4787	74.84%
Total Cost	$59,269,781	$800.26	$148.17	$1.9757	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E58. Critical Results for Sensitivity Scenario 5E (Reduce Capital Cost Discount Rate by 1%)[a], Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5E[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,846	1	0.00%
Acres of SG	37,225	37,200	(25)	(0.07%)
Total farm acres[d]	187,760	187,738	(22)	(0.01%)
HES Dry Ton Production	313,266	313,331	65	0.02%
HES Wet Ton Production	950,719	948,781	(1,938)	(0.20%)
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.50	0.00	0.00%
Average SG Dry Ton Yield per Acre	2.69	2.69	0.00	0.00%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$52,923,658	($678,545)	(1.27%)
Cost per Acre of All Biomass feedstock Produced	723.67	714.74	(8.93)	(1.23%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	132.31	(1.70)	(1.27%)
Cost per Gallon of Fuel	1.7867	1.7641	(0.0226)	(1.26%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$117,799,665	($449,630)	(0.38%)
Annualized Investment Costs	14,919,357	14,244,997	(674,360)	(4.52%)
Percent of All Costs	27.8%	26.9%	(0.9%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	192.38	(9.04)	(4.49%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	35.61	(1.69)	(4.52%)
Cost per Gallon of Fuel	0.4973	0.4748	(0.0225)	(4.52%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$38,678,661	($4,184)	(0.01%)
Percent of All Costs	72.2%	73.08%	0.9%	--
Cost per Acre of All Biomass feedstock Produced	522.25	522.36	0.11	0.02%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	96.70	(0.01)	(0.01%)
Cost per Gallon of Fuel	1.2894	1.29	(1.29)	(0.01%)

[a] In this scenario, the discount rate is reduced by 1 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E59. Sensitivity Scenario 5E (Reduce Capital Cost Discount Rate by 1%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	237,815	sq ft	$ 109,395	$ 27,670	0.19%
Office Space	7,405	sq ft	1,110,750	175,731	1.23%
Pole Barns	89,048	sq ft	1,246,672	197,235	1.38%
Inside Machinery Storage	26,157	sq ft	3,138,840	496,594	3.49%
Headquarters Land	245,220	sq ft	27,955	2,159	0.02%
Purchased Machinery					
Tractor Size 1	23	#	3,968,880	729,451	5.12%
Tractor Size 2	37	#	4,885,850	759,485	5.33%
Planter	7	#	461,188	260,311	1.83%
Harvester	13	#	4,804,974	1,150,844	8.08%
In-Field Buggy	49	#	1,788,500	270,246	1.90%
Transport Trucks	114	#	12,084,000	1,870,258	13.13%
High-Energy Sorghum Trailers	114	#	5,916,600	630,323	4.42%
Switchgrass Trailers	20	#	700,000	82,307	0.58%
Support Vehicles	26	#	910,000	209,960	1.47%
Storage Handling	36	#	4,428,900	562,015	3.95%
Disc	9	#	404,966	109,129	0.77%
Bedder	14	#	278,600	27,906	0.20%
Fertilizer Toolbar	8	#	120,000	20,551	0.14%
Cultivator	3	#	283,500	65,106	0.46%
Sprayer	1	#	226,628	38,231	0.27%
Hay Cutter	6	#	695,178	158,094	1.11%
Wheel Rake	4	#	86,500	25,044	0.18%
Square Baler	7	#	678,783	110,104	0.77%
Hipper	13	#	310,765	53,222	0.37%
Rolling Cultivator	4	#	121,160	33,429	0.23%
Land Plane	9	#	355,500	92,944	0.65%
Bale Wagon	15	#	2,181,480	447,091	3.14%
Hay Squeeze	12	#	1,638,300	324,373	2.28%
Irrigation					
Develop Irrigation Well Size 2	75	#	19,815,938	1,450,714	10.18%
Re-Lift Pump		#			
SG Custom Establishment	246		4,243,500	375,764	2.64%
SG Harvest Production	37,200	acres	11,096,760	860,061	6.04%
SG Insurance Production	40,000	acres	11,932,000	924,797	6.49%
Storage					
Storage Land	6,021,120	sq ft	1,204,224	166,435	1.17%
Purchase Storage	147	#	15,670,200	1,313,112	9.22%
Silo Cover	3,492,720	sq ft	873,180	224,303	1.57%
Total Cost			$117,799,665	$14,244,997	100.00%

Table E60. Sensitivity Scenario 5E (Reduce Capital Cost Discount Rate by 1%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 962,173	2.49%
Land				
HES Land	acres	36,846	2,118,645	5.48%
SG Production Land	acres	37,200	837,000	2.16%
SG Insurance Land	acres	40,000	700,000	1.81%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.50%
Hire Part-Time Labor	hours	40,499	546,391	1.41%
Irrigation				
Pump Groundwater	acre-inches	614,219	3,438,453	8.89%
HES Field Operations				
Disc	n/a	n/a	129,446	0.33%
Disc	n/a	n/a	129,446	0.33%
Land Plane	n/a	n/a	216,356	0.56%
Bed	n/a	n/a	68,490	0.18%
Hip Beds	n/a	n/a	70,887	0.18%
Fertilize	n/a	n/a	6,986,279	18.06%
Hip Beds	n/a	n/a	70,887	0.18%
Spray	n/a	n/a	441,259	1.14%
Condition Beds	n/a	n/a	73,211	0.19%
Always Planting	n/a	n/a	1,469,610	3.80%
Cultivate	n/a	n/a	81,991	0.21%
Always Harvesting	n/a	n/a	1,977,893	5.11%
Support Vehicles	n/a	n/a	24,884	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,393,604	8.77%
Transportation				
Transport HES	wet tons	948,781	2,251,939	5.82%
Transport SG	dry tons	100,000	353,171	0.91%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	7,514	75,370	0.19%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,733	66,718	0.17%
Overhead Management				
Overhead Management	persons	46	3,876,855	10.02%
Total cost			$38,678,661	100.00%

Table E61. Summary of Sensitivity Scenario 5E (Reduce Capital Cost Discount Rate by 1%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$14,244,997	$192.38	$ 35.61	$0.475	26.92%
Annual Operating Costs	38,678,661	522.36	96.70	1.289	73.08%
Total Cost	$52,923,658	$714.74	$132.31	$1.764	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E62. Critical Results for Sensitivity Scenario 5F (Consider Only Farm Gate Costs)[a], Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5F[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	30,980	(5,865	(15.92%)
Acres of SG	37,225	35,998	(1,227)	(3.30%)
Total farm acres[d]	187,760	168,938	18,822	(10.02)
HES Dry Ton Production	313,266	315,906	2,640	0.84%
HES Wet Ton Production	950,719	952,517	1,798	0.19%
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	10.20	1.70	19.97%
Average SG Dry Ton Yield per Acre	2.69	2.78	0	3.27%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$34,718,984	($18,883,219)	(35.23%)
Cost per Acre of All Biomass feedstock Produced	723.67	518.36	(205.31)	(28.37%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	86.80	(47.21)	(35.23%)
Cost per Gallon of Fuel	1.7867	1.1573	(0.6294)	(35.23%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$73,253,052	($44,996,243)	(38.05%)
Annualized Investment Costs	14,919,357	9,255,284	(5,664,073)	(37.96%)
Percent of All Costs	27.8%	26.7%	(1.1%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	138.18	(63.24)	(31.40%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	23.14	(14.16)	(37.97%)
Cost per Gallon of Fuel	0.4973	0.3085	(0.1888)	(37.96%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$25,463,700	($13,219,145)	(34.17%)
Percent of All Costs	72.2%	73.3%	1.1%	--
Cost per Acre of All Biomass feedstock Produced	522.25	380.18	(142.07)	(27.20%) 0
Cost per Dry Ton of All Biomass feedstock Produced	96.71	63.66	(33.05)	(34.18%)
Cost per Gallon of Fuel	1.2894	0.8488	(0.3796)	(30.90%)

[a] In this scenario, only the farm gate costs are considered. All costs associated with transportation and storage are removed.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E63. Sensitivity Scenario 5F (Consider Only Farm Gate Costs) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	182,206	sq ft	$83,815	$22,568	0.24%
Office Space	6,698	sq ft	1,004,700	176,542	1.91%
Pole Barns	62,172	sq ft	870,408	152,945	1.65%
Inside Machinery Storage	25,582	sq ft	3,069,840	539,421	5.83%
Headquarters Land	188,904	sq ft	21,535	1,884	0.02%
Purchased Machinery					
Tractor Size 1	28	#	4,831,680	925,076	10.00%
Tractor Size 2	41	#	5,414,050	883,821	9.55%
Planter	6	#	395,304	226,342	2.45%
Harvester	10	#	3,696,134	911,289	9.85%
In-Field Buggy	69	#	2,518,500	398,719	4.31%
Transport Trucks	0	#	0	0	0.00%
High-Energy Sorghum Trailers	0	#	0	0	0.00%
Switchgrass Trailers	0	#	0	0	0.00%
Support Vehicles	22	#	770,000	183,772	1.99%
Storage Handling	0	#	0	0	0.00%
Disc	13	#	584,950	161,790	1.75%
Bedder	14	#	278,600	29,893	0.32%
Fertilizer Toolbar	7	#	105,000	18,701	0.20%
Cultivator	2	#	189,000	44,722	0.48%
Sprayer	1	#	226,628	39,782	0.43%
Hay Cutter	5	#	579,315	136,271	1.47%
Wheel Rake	3	#	64,875	19,249	0.21%
Square Baler	6	#	581,814	99,356	1.07%
Hipper	10	#	239,050	42,577	0.46%
Rolling Cultivator	4	#	121,160	34,293	0.37%
Land Plane	14	#	553,000	148,494	1.60%
Bale Wagon	13	#	1,890,616	402,440	4.35%
Hay Squeeze	7	#	955,675	196,707	2.13%
Irrigation					
Develop Irrigation Well Size 2	68	#	17,966,450	1,450,184	15.67%
Re-Lift Pump	207	#	3,570,750	340,733	3.68%
SG Custom Establishment					
SG Harvest Production	35,998	acres	10,738,203	789,946	8.54%
SG Insurance Production	40,000	acres	11,932,000	877,767	9.48%
Storage					
Storage Land	0	sq ft	0	0	0.00%
Purchase Storage	0	#	0	0	0.00%
Silo Cover	0	sq ft	0	0	0.00%
Total Cost			$73,253,052	$9,255,284	100.00%

Table E64. Sensitivity Scenario 5F (Consider Only Farm Gate Costs) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$633,683	2.49%
Land				
HES Land	acres	30,980	1,781,350	7.00%
SG Production Land	acres	35,998	809,955	3.18%
SG Insurance Land	acres	40,000	700,000	2.75%
Labor				
Hire Full-Time Labor	persons	40	1,957,100	7.69%
Hire Part-Time Labor	hours	31,599	426,319	1.67%
Irrigation				
Pump Groundwater	acre-inches	516,437	2,891,060	11.35%
HES Field Operations				
Disc	n/a	n/a	108,838	0.43%
Disc	n/a	n/a	108,838	0.43%
Land Plane	n/a	n/a	181,912	0.71%
Bed	n/a	n/a	57,586	0.23%
Hip Beds	n/a	n/a	59,602	0.23%
Fertilize	n/a	n/a	5,874,081	23.07%
Hip Beds	n/a	n/a	59,602	0.23%
Spray	n/a	n/a	371,011	1.46%
Condition Beds	n/a	n/a	61,556	0.24%
Always Planting	n/a	n/a	1,235,652	4.85%
Cultivate	n/a	n/a	68,938	0.27%
Always Harvesting	n/a	n/a	1,796,673	7.06%
Support Vehicles	n/a	n/a	20,923	0.08%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,305,583	12.98%
Transportation				
Transport HES	wet tons	952,517	0	0.00%
Transport SG	dry tons	100,000	0	0.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	12,599	126,388	0.50%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,418	64,563	0.25%
Overhead Management				
Overhead Management	persons	33	2,762,462	10.85%
Total cost			$25,463,700	100.00%

Table E65. Summary of Sensitivity Scenario 5F (Consider Only Farm Gate Costs), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$9,255,284	$138.18	$23.14	$0.3085	26.66%
Annual Operating Costs	$25,463,700	$380.18	$63.66	$0.8488	73.34%
Total Cost	$34,718,984	$518.36	$86.80	$1.1573	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario, farm gate costs are the only costs considered.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E66. Critical Results for Sensitivity Scenario 5G (Consider Only "Just-In-Time" Deliveries)[a], Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5G[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	19,199	(17,646)	(47.89%)
Acres of SG	37,225	89,851	52,626	141.37%
Total farm acres[d]	187,760	187,448	(312)	(0.17%)
HES Dry Ton Production	313,266	167,556	(145,710)	(46.51%)
HES Wet Ton Production	950,719	517,182	(433,537)	(45.60%)
SG Dry Ton Production	100,000	232,444	132,444	132.44%
Average HES Dry Ton Yield per Acre	8.50	8.73	0.23	2.67%
Average SG Dry Ton Yield per Acre	2.69	2.59	(0.10)	(3.83%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	56,048,490.27	$2,446,287	4.56%
Cost per Acre of All Biomass feedstock Produced	723.67	513.97	(209.70)	(28.98%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	140.12	6.11	4.56%
Cost per Gallon of Fuel	1.7867	1.8683	0.0816	4.57%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$122,876,866	$4,627,571	3.91%
Annualized Investment Costs	14,919,357	16,139,280	1,219,923	8.18%
Percent of All Costs	27.8%	28.8%	1.0%	--
Cost per Acre of All Biomass feedstock Produced	201.42	148.00	(53.42)	(26.52%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	40.35	3.05	8.17%
Cost per Gallon of Fuel	0.4973	0.5380	0.0407	8.18%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$39,909,210	$1,226,365	3.17%
Percent of All Costs	72.2%	71.20%	(1.0%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	365.97	(156.28)	(29.92%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	99.77	3.06	3.17%
Cost per Gallon of Fuel	1.2894	1.3303	0.0409	3.17%

[a] In this scenario, only biomass feedstocks that are delivered just-in-time are considered, i.e., there is no storage of biomass feedstocks from one period to the next.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E67. Sensitivity Scenario 5G (Consider Only "Just-In-Time" Deliveries) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	271,005	sq ft	$124,662	$33,567	0.21%
Office Space	10,905	sq ft	1,635,750	287,428	1.78%
Pole Barns	100,138	sq ft	1,401,932	246,342	1.53%
Inside Machinery Storage	29,912	sq ft	3,589,440	630,723	3.91%
Headquarters Land	281,910	sq ft	32,138	2,811	0.02%
Purchased Machinery					
Tractor Size 1	9	#	1,553,040	297,346	1.84%
Tractor Size 2	55	#	7,262,750	1,185,613	7.35%
Tractor Size 3	0	#	0.00	0.00	0.00%
Planter	3	#	197,652	113,171	0.70%
Harvester	9	#	3,326,520	820,160	5.08%
In-Field Buggy	64	#	2,336,000	369,826	2.29%
Transport Trucks	165	#	17,490,000	2,829,281	17.53%
High-Energy Sorghum Trailers	165	#	8,563,500	972,829	6.03%
Switchgrass Trailers	50	#	1,750,000	218,134	1.35%
Support Vehicles	14	#	490,000	116,946	0.72%
Storage Handling	43	#	5,290,075	712,403	4.41%
Disc	4	#	179,985	49,781	0.31%
Bedder	2	#	39,800	4,270	0.03%
Fertilizer Toolbar	4	#	60,000	10,687	0.07%
Cultivator	2	#	189,000	44,722	0.28%
Sprayer	3	#	679,884	119,347	0.74%
Hay Cutter	17	#	1,969,671	463,322	2.87%
Wheel Rake	10	#	216,250	64,162	0.40%
Square Baler	21	#	2,036,349	347,745	2.15%
Hipper	4	#	95,620	17,031	0.11%
Rolling Cultivator	2	#	60,580	17,146	0.11%
Land Plane	4	#	158,000	42,427	0.26%
Bale Wagon	40	#	5,817,280	1,238,278	7.67%
Hay Squeeze	31	#	4,232,275	871,131	5.40%
Irrigation					
Develop Irrigation Well Size 2	34	#	8,983,225	725,092	4.49%
Re-Lift Pump	128	#	2,208,000	210,695	1.31%
SG Custom Establishment					
SG Harvest Production	89,850	acres	26,802,312	1,971,688	12.22%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.44%
Storage					
Storage Land	737,280	sq ft	147,456	22,961	0.14%
Purchase Storage	18	#	1,918,800	176,298	1.09%
Silo Cover	427,680	sq ft	106,920	28,150	0.17%
Total Cost			$122,876,866	$16,139,280	100.00%

Table E68. Sensitivity Scenario 5G (Consider Only "Just-In-Time" Deliveries) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$992,796	2.49%
Land				
HES Land	acres	19,199	1,103,943	2.77%
SG Production Land	acres	89,851	2,021,648	5.07%
SG Insurance Land	acres	40,000	700,000	1.75%
Labor				
Hire Full-Time Labor	persons	250	12,231,875	30.65%
Hire Part-Time Labor	hours	1,348	18,186	0.05%
Irrigation				
Pump Groundwater	acre-inches	320,037	1,791,600	4.49%
HES Field Operations				
Disc	n/a	n/a	67,447	0.17%
Disc	n/a	n/a	67,447	0.17%
Land Plane	n/a	n/a	112,732	0.28%
Bed	n/a	n/a	35,686	0.09%
Hip Beds	n/a	n/a	36,935	0.09%
Fertilize	n/a	n/a	3,640,188	9.12%
Hip Beds	n/a	n/a	36,935	0.09%
Spray	n/a	n/a	229,917	0.58%
Condition Beds	n/a	n/a	38,146	0.10%
Always Planting	n/a	n/a	765,738	1.92%
Cultivate	n/a	n/a	42,721	0.11%
Always Harvesting	n/a	n/a	1,050,284	2.63%
Support Vehicles	n/a	n/a	12,966	0.03%
SG Field Operations				
Grow and Harvest	n/a	n/a	8,135,815	20.39%
Transportation				
Transport HES	wet tons	517,182	1,228,409	3.08%
Transport SG	dry tons	232,444	820,924	2.06%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	307	3,075	0.01%
Transfer Tractor Hours 152 hp to 100 hp	hours	23,507	161,147	0.40%
Overhead Management				
Overhead Management	persons	54	4,562,635	11.43%
Total cost			$39,909,210	100.00%

Table E69. Summary of Sensitivity Scenario 5G (Consider Only "Just-In-Time" Deliveries), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$16,139,280	$148.00	$40.35	$0.5380	28.80%
Annual Operating Costs	39,909,210	365.97	99.77	1.3303	71.20%
Total Cost	$56,048,490	$513.97	$140.12	$1.8683	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E70. Critical Results for Sensitivity Scenario 5H (Consider Only "Just-In-Time" Deliveries with Averaged Trafficable Days), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5G[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	19,080	(17,765)	(48.22%)
Acres of SG	37,225	89,851	52,626	141.37%
Total farm acres[d]	187,760	187,091	(669)	(0.36%
HES Dry Ton Production	313,266	167,556	(145,710)	(46.51%)
HES Wet Ton Production	950,719	517,182	(433,537)	(45.60%)
SG Dry Ton Production	100,000	232,444	132,444	132.44%
Average HES Dry Ton Yield per Acre	8.50	8.78	0.28	3.32%
Average SG Dry Ton Yield per Acre	2.69	2.59	(0.10)	(3.83%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$52,582,797	($1,019,406)	(1.90%)
Cost per Acre of All Biomass feedstock Produced	723.67	482.72	(240.95)	(33.30%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	131.46	(2.55)	(1.91%)
Cost per Gallon of Biofuel	1.7867	1.7528	(0.0339)	(1.90%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$102,611,410	($15,637,885)	(13.22%)
Annualized Investment Costs	14,919,357	12,723,001	(2,196,356)	(14.72%)
Percent of All Costs	27.8%	24.2%	(3.6%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	116.80	(84.62)	(42.01%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	31.81	(5.49)	(14.73%)
Cost per Gallon of Biofuel	0.4973	0.4241	(0.0732)	(14.72%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$39,859,796	$1,176,951	3.04%
Percent of All Costs	72.2%	75.80%	3.6%	--
Cost per Acre of All Biomass feedstock Produced	522.25	365.92	(156.33)	(29.93%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	99.65	2.94	3.04%
Cost per Gallon of Biofuel	1.2894	1.3287	0.0393	3.04%

[a] In this scenario, only biomass feedstocks that are delivered just-in-time are considered. Trafficable days are set at the 75 percent probability level and each periods trafficable days are averaged with the period before and the period after.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E71. Sensitivity Scenario 5H (Consider Only "Just-In-Time" Deliveries with Averaged Trafficable Days) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	200,590	sq ft	$92,271	$24,845	0.20%
Office Space	10,894	sq ft	$1,634,100	$287,138	2.26%
Pole Barns	73,224	sq ft	$1,025,136	$180,133	1.42%
Inside Machinery Storage	21,624	sq ft	$2,594,880	$455,963	3.58%
Headquarters Land	211,484	sq ft	$24,109	$2,109	0.02%
Purchased Machinery					
Tractor Size 1	10	#	$1,725,600	$330,384	2.60%
Tractor Size 2	33	#	$4,357,650	$711,368	5.59%
Tractor Size 3	0	#	$0	$0	0.00%
Planter	3	#	$197,652	$113,171	0.89%
Harvester	6	#	$2,217,680	$546,773	4.30%
In-Field Buggy	43	#	$1,569,500	$248,477	1.95%
Transport Trucks	110	#	$11,660,000	$1,886,188	14.83%
High-Energy Sorghum Trailers	110	#	$5,709,000	$648,552	5.10%
Switchgrass Trailers	38	#	$1,330,000	$165,782	1.30%
Support Vehicles	9	#	$315,000	$75,179	0.59%
Storage Handling	29	#	$3,567,725	$480,458	3.78%
Disc	4	#	$179,985	$49,781	0.39%
Bedder	2	#	$39,800	$4,270	0.03%
Fertilizer Toolbar	4	#	$60,000	$10,687	0.08%
Cultivator	2	#	$189,000	$44,722	0.35%
Sprayer	2	#	$453,256	$79,564	0.63%
Hay Cutter	13	#	$1,506,219	$354,305	2.78%
Wheel Rake	7	#	$151,375	$44,914	0.35%
Square Baler	16	#	$1,551,504	$264,949	2.08%
Hipper	3	#	$71,715	$12,773	0.10%
Rolling Cultivator	2	#	$60,580	$17,146	0.13%
Land Plane	5	#	$197,500	$53,034	0.42%
Bale Wagon	30	#	$4,362,960	$928,708	7.30%
Hay Squeeze	23	#	$3,140,075	$646,323	5.08%
Irrigation					
Develop Irrigation Well Size 2	36	#	$9,511,650	$767,745	6.03%
Re-Lift Pump	128	#	$2,208,000	$210,695	1.66%
SG Custom Establishment					
SG Harvest Production	89,850	acres	$26,802,312	$1,971,688	15.50%
SG Insurance Production	40,000	acres	$11,932,000	$877,767	6.90%
Storage					
Storage Land	737,280	sq ft	$147,456	$22,961	0.18%
Purchase Storage	18	#	$1,918,800	$176,298	1.39%
Silo Cover	427,680	sq ft	$106,920	$28,150	0.22%
Total Cost			$102,611,410	$12,723,001	100.00%

Table E72. Sensitivity Scenario 5H (Consider Only "Just-In-Time" Deliveries with Averaged Trafficable Days) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$991,567	2.49%
Land				
HES Land	acres	19,080	1,097,100	2.75%
SG Production Land	acres	89,851	2,021,648	5.07%
SG Insurance Land	acres	40,000	700,000	1.76%
Labor				
Hire Full-Time Labor	persons	250	12,231,875	30.69%
Hire Part-Time Labor	hours	1,337	18,039	0.05%
Irrigation				
Pump Groundwater	acre-inches	318,050	1,780,473	4.47%
HES Field Operations				
Disc	n/a	n/a	67,029	0.17%
Disc	n/a	n/a	67,029	0.17%
Land Plane	n/a	n/a	112,032	0.28%
Bed	n/a	n/a	35,465	0.09%
Hip Beds	n/a	n/a	36,706	0.09%
Fertilize	n/a	n/a	3,617,580	9.08%
Hip Beds	n/a	n/a	36,706	0.09%
Spray	n/a	n/a	228,489	0.57%
Condition Beds	n/a	n/a	37,910	0.10%
Always Planting	n/a	n/a	760,982	1.91%
Cultivate	n/a	n/a	42,456	0.11%
Always Harvesting	n/a	n/a	1,046,535	2.63%
Support Vehicles	n/a	n/a	12,885	0.03%
SG Field Operations				
Grow and Harvest	n/a	n/a	8,135,815	20.41%
Transportation				
Transport HES	wet ton	517,182	1,228,409	3.08%
Transport SG	dry tons	232,444	820,924	2.06%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	832	8,347	0.02%
Transfer Tractor Hours 152 hp to 100 hp	hours	23,507	161,147	0.40%
Overhead Management				
Overhead Management	persons	54	4,562,635	11.45%
Total cost			$39,859,796	100.00%

Table E73. Summary of Sensitivity Scenario 5H (Consider Only "Just-In-Time" Deliveries with Averaged Trafficable Days), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$12,723,001	$116.80	$31.81	$0.4241	24.20%
Annual Operating Costs	39,859,796	365.92	99.65	1.3287	75.80%
Total Cost	$52,582,797	$482.72	$131.46	$1.7528	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E74. Critical Results for Sensitivity Scenario 5I (Consider Only Part-Time Labor), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5I[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	31,301	(5,544)	(15.05%)
Acres of SG	37,225	36,184	(1,041)	(2.80%)
Total farm acres[d]	187,760	170,0	(17,673)	(9.41%)
HES Dry Ton Production	313,266	314,404	1,138	0.36%
HES Wet Ton Production	950,719	937,419	(13,300)	(1.40%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	10.04	1.54	18.17%
Average SG Dry Ton Yield per Acre	2.69	2.76	0.07	2.74%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$47,793,589	(5,808,613)	(10.84%)
Cost per Acre of All Biomass feedstock Produced	723.67	708.21	(15.46)	(2.14%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	119.48	(14.53)	(10.84%)
Cost per Gallon of Fuel	1.7867	1.5931	(0.1936)	(10.83%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$129,017,318	10,768,023	9.11%
Annualized Investment Costs	14,919,357	16,327,308	1,407,950.78	9.44%
Percent of All Costs	27.8%	34.2%	0.06	--
Cost per Acre of All Biomass feedstock Produced	201.42	241.94	40.52	20.12%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	40.82	3.52	9.43%
Cost per Gallon of Fuel	0.4973	0.5442	0.0469	9.44%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$31,466,281	(7,216,563)	(18.66%)
Percent of All Costs	72.2%	65.8%	(0.06)	--
Cost per Acre of All Biomass feedstock Produced	522.25	466.27	(55.98)	(10.72%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	78.67	(18.04)	(18.66%)
Cost per Gallon of Fuel	1.2894	1.0489	(0.2405)	(18.65%)

[a] In this scenario, only part-time labor is considered.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E75. Sensitivity Scenario 5I (Consider Only Part-Time Labor) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	237,400	sq ft	$109,204	$29,405	0.18%
Office Space	6,749	sq ft	1,012,350	177,886	1.09%
Pole Barns	86,779	sq ft	1,214,906	213,479	1.31%
Inside Machinery Storage	28,398	sq ft	3,407,760	598,799	3.67%
Headquarters Land	243,852	sq ft	27,799	2,432	0.01%
Purchased Machinery					
Tractor Size 1	18	#	3,106,080	594,691	3.64%
Tractor Size 2	58	#	7,658,900	1,250,283	7.66%
Tractor Size 3	0	#	0	0	0.00%
Planter	7	#	461,188	264,065	1.62%
Harvester	12	#	4,435,360	1,093,547	6.70%
In-Field Buggy	62	#	2,263,000	358,269	2.19%
Transport Trucks	154	#	16,324,000	2,640,663	16.17%
High-Energy Sorghum Trailers	154	#	7,992,600	907,973	5.56%
Switchgrass Trailers	18	#	630,000	78,528	0.48%
Support Vehicles	22	#	770,000	183,772	1.13%
Storage Handling	45	#	5,536,125	745,538	4.57%
Disc	7	#	314,973	87,118	0.53%
Bedder	3	#	59,700	6,406	0.04%
Fertilizer Toolbar	4	#	60,000	10,687	0.07%
Cultivator	2	#	189,000	44,722	0.27%
Sprayer	1	#	226,628	39,782	0.24%
Hay Cutter	6	#	695,178	163,525	1.00%
Wheel Rake	4	#	86,500	25,665	0.16%
Square Baler	7	#	678,783	115,915	0.71%
Hipper	4	#	95,620	17,031	0.10%
Rolling Cultivator	4	#	121,160	34,293	0.21%
Land Plane	7	#	276,500	74,247	0.45%
Bale Wagon	13	#	1,890,616	402,440	2.46%
Hay Squeeze	11	#	1,501,775	309,111	1.89%
Irrigation					
Develop Irrigation Well Size 2	80	#	21,137,000	1,706,099	10.45%
Re-Lift Pump	209	#	3,605,250	344,026	2.11%
SG Custom Establishment					
SG Harvest Production	36,184	acres	10,793,655	794,026	4.86%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.38%
Storage					
Storage Land	6,922,240	sq ft	1,384,448	215,581	1.32%
Purchase Storage	169	#	18,015,400	1,655,238	10.14%
Silo Cover	4,015,440	sq ft	1,003,860	264,300	1.62%
Total Cost			$129,017,318	$16,327,308	100%

Table E76. Sensitivity Scenario 5I (Consider Only Part-Time Labor) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$782,688	2.49%
Land				
HES Land	acres	31,301	1,799,808	5.72%
SG Production Land	acres	36,184	814,140	2.59%
SG Insurance Land	acres	40,000	700,000	2.22%
Labor				
Hire Full-Time Labor	persons	0	0	0.00%
Hire Part-Time Labor	hours	333,814	4,503,647	14.31%
Irrigation				
Pump Groundwater	acre-inches	521,787	2,921,014	9.28%
HES Field Operations				
Disc	n/a	n/a	109,966	0.35%
Disc	n/a	n/a	109,966	0.35%
Land Plane	n/a	n/a	183,797	0.58%
Bed	n/a	n/a	58,183	0.18%
Hip Beds	n/a	n/a	60,219	0.19%
Fertilize	n/a	n/a	5,934,940	18.86%
Hip Beds	n/a	n/a	60,219	0.19%
Spray	n/a	n/a	374,855	1.19%
Condition Beds	n/a	n/a	62,194	0.20%
Always Planting	n/a	n/a	1,248,454	3.97%
Cultivate	n/a	n/a	69,653	0.22%
Always Harvesting	n/a	n/a	1,793,728	5.70%
Support Vehicles	n/a	n/a	21,140	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,319,195	10.55%
Transportation				
Transport HES	wet ton	937,419	2,230,707	7.09%
Transport SG	dry tons	100,000	353,171	1.12%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	1,278	12,822	0.04%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,467	64,896	0.21%
Overhead Management				
Overhead Management	persons	46	3,876,855	12.32%
Total cost			$31,466,281	100.00%

Table E77. Summary of Sensitivity Scenario 5I (Consider Only Part-Time Labor), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$16,327,308	$241.94	$40.82	$0.5442	34.16%
Annual Operating Costs	31,466,281	466.27	78.67	1.0489	65.84%
Total Cost	$47,793,589	$708.21	$119.48	$1.5931	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E78. Critical Results for Sensitivity Scenario 5J (Lease All Transportation Equipment), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5J[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	35,847	(998)	(2.71%)
Acres of SG	37,225	37,297	72	0.19%
Total farm acres[d]	187,760	184,838	(2,922)	(1.56%)
HES Dry Ton Production	313,266	313,233	(33)	(0.01%)
HES Wet Ton Production	950,719	953,730	3,011	0.32%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.74	0.24	2.80%
Average SG Dry Ton Yield per Acre	2.69	2.68	(0.01)	(0.33%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$51,898,003	($1,704,200)	(3.18%)
Cost per Acre of All Biomass feedstock Produced	723.67	709.33	(14.34)	(1.98%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	129.71	(4.30)	(3.21%)
Cost per Gallon of Fuel	1.7867	1.7294	(0.0573)	(3.21%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$98,564,853	$19,684,442)	(16.65%)
Annualized Investment Costs	14,919,357	11,996,610	(2,922,747)	(19.59%)
Percent of All Costs	27.8%	23.1%	(4.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	164.01	(37.41)	(18.57%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	29.99	(7.31)	(19.59%)
Cost per Gallon of Fuel	0.4973	0.3999	(0.0974)	(19.59%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$39,886,392	$1,203,547	3.11%
Percent of All Costs	72.2%	76.9%	4.7%	--
Cost per Acre of All Biomass feedstock Produced	522.25	545.31	23.06	4.42%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	99.72	3.01	3.11%
Cost per Gallon of Fuel	1.2894	1.3295	0.0401	3.11%

[a] In this scenario, all transportation equipment is leased.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E79. Sensitivity Scenario 5J (Lease All Transportation Equipment) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	192,327	sq ft	$88,470	$23,822	0.20%
Office Space	7,315	sq ft	1,097,250	192,805	1.61%
Pole Barns	67,628	sq ft	946,792	166,367	1.39%
Inside Machinery Storage	24,878	sq ft	2,985,360	524,576	4.37%
Headquarters Land	199,642	sq ft	22,759	1,991	0.02%
Purchased Machinery					
Tractor Size 1	22	#	3,796,320	726,845	6.06%
Tractor Size 2	37	#	4,885,850	797,594	6.65%
Tractor Size 3	0	#	0	0	0.00%
Planter	7	#	461,188	264,065	2.20%
Harvester	11	#	4,065,747	1,002,418	8.36%
In-Field Buggy	49	#	1,788,500	283,148	2.36%
Transport Trucks	0	#	0	0	0.00%
High-Energy Sorghum Trailers	0	#	0	0	0.00%
Switchgrass Trailers	0	#	0	0	0.00%
Support Vehicles	26	#	910,000	217,185	1.81%
Storage Handling	36	#	4,428,900	596,430	4.97%
Disc	10	#	449,962	124,454	1.04%
Bedder	13	#	258,700	27,758	0.23%
Fertilizer Toolbar	8	#	120,000	21,373	0.18%
Cultivator	3	#	283,500	67,084	0.56%
Sprayer	1	#	226,628	39,782	0.33%
Hay Cutter	6	#	695,178	163,525	1.36%
Wheel Rake	4	#	86,500	25,665	0.21%
Square Baler	7	#	678,783	115,915	0.97%
Hipper	14	#	334,670	59,608	0.50%
Rolling Cultivator	4	#	121,160	34,293	0.29%
Land Plane	9	#	355,500	95,461	0.80%
Bale Wagon	15	#	2,181,480	464,354	3.87%
Hay Squeeze	12	#	1,638,300	337,212	2.81%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	13.87%
Re-Lift Pump	239	#	4,122,750	393,407	3.28%
SG Custom Establishment					
SG Harvest Production	37,297	acres	11,125,695	818,452	6.82%
SG Insurance Production	40,000	acres	11,932,000	877,767	7.32%
Storage					
Storage Land	6,062,080	sq ft	1,212,416	188,793	1.57%
Purchase Storage	148	#	15,776,800	1,449,558	12.08%
Silo Cover	3,516,480	sq ft	879,120	231,458	1.93%
Total Cost			$98,564,853	$11,996,610	100.00%

Table E80. Sensitivity Scenario 5J (Lease All Transportation Equipment) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$992,602	2.49%
Land				
HES Land	acres	35,847	2,061,203	5.17%
SG Production Land	acres	37,297	839,183	2.10%
SG Insurance Land	acres	40,000	700,000	1.75%
Labor				
Hire Full-Time Labor	persons	180	8,806,950	22.08%
Hire Part-Time Labor	hours	32,678	440,882	1.11%
Irrigation				
Pump Groundwater	acre-inches	597,569	3,345,249	8.39%
HES Field Operations				
Disc	n/a	n/a	125,937	0.32%
Disc	n/a	n/a	125,937	0.32%
Land Plane	n/a	n/a	210,491	0.53%
Bed	n/a	n/a	66,633	0.17%
Hip Beds	n/a	n/a	68,965	0.17%
Fertilize	n/a	n/a	6,796,906	17.04%
Hip Beds	n/a	n/a	68,965	0.17%
Spray	n/a	n/a	429,298	1.08%
Condition Beds	n/a	n/a	71,226	0.18%
Always Planting	n/a	n/a	1,429,774	3.58%
Cultivate	n/a	n/a	79,769	0.20%
Always Harvesting	n/a	n/a	1,950,762	4.89%
Support Vehicles	n/a	n/a	24,210	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,400,707	8.53%
Transportation				
Lease Semi trucks and Trailers	n/a	n/a	1,142,325	2.86%
Transport HES	wet ton	953,730	2,245,344	5.63%
Transport SG	dry tons	100,000	353,171	0.89%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	8,016	80,407	0.20%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,758	66,892	0.17%
Overhead Management				
Overhead Management	persons	47	3,962,577	9.93%
Total cost			$39,886,392	100%

Table E81. Summary of Sensitivity Scenario 5J (Lease All Transportation Equipment), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$11,996,610	$164.01	$29.99	$0.3999	23.12%
Annual Operating Costs	39,886,392	545.31	99.72	1.3295	76.88%
Total Cost	$51,898,003	$709.33	$129.71	$1.7294	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E82. Critical Results for Sensitivity Scenario 5K (Periodic Storage Losses are Set at 5%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5K[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	42,598	5,753	15.61%
Acres of SG	37,225	36,677	(548)	(1.47%)
Total farm acres[d]	187,760	204,471	16,711	8.90%
HES Dry Ton Production	313,266	372,955	59,689	19.05%
HES Wet Ton Production	950,719	1,120,729	170,710	17.88%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.76	0.26	3.00%
Average SG Dry Ton Yield per Acre	2.69	2.73	0.04	1.36%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$62,352,097	$8,749,894	16.32%
Cost per Acre of All Biomass feedstock Produced	723.67	786.53	62.86	8.69%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	155.88	21.87	16.32%
Cost per Gallon of Fuel	1.7867	2.0784	0.2917	16.33%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$137,050,314	$18,801,019	15.90%
Annualized Investment Costs	14,919,357	17,682,598	2,763,241	18.52%
Percent of All Costs	27.8%	28.4%	0.6%	--
Cost per Acre of All Biomass feedstock Produced	201.42	223.05	21.63	10.74%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	44.21	6.91	18.52%
Cost per Gallon of Fuel	0.4973	0.5894	0.0921	18.52%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$44,669,500	$5,986,655	15.48%
Percent of All Costs	72.2%	71.6%	(0.6%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	563.48	41.23	7.89%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	111.67	14.96	15.47%
Cost per Gallon of Fuel	1.2894	1.4890	0.1996	15.48%

[a] In this scenario, periodic storage losses are at 5 percent.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E83. Sensitivity Scenario 5K (Periodic Storage Losses are Set at 5%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	282,264	sq ft	$129,841	$34,962	0.20%
Office Space	7,928	sq ft	1,189,200	208,962	1.18%
Pole Barns	104,705	sq ft	1,465,870	257,577	1.46%
Inside Machinery Storage	32,463	sq ft	3,895,560	684,513	3.87%
Headquarters Land	290,192	sq ft	33,082	2,894	0.02%
Purchased Machinery					
Tractor Size 1	26	#	4,486,560	858,999	4.86%
Tractor Size 2	47	#	6,206,350	1,013,160	5.73%
Tractor Size 3	0	#	0	$0	0.00%
Planter	8	#	527,072	301,789	1.71%
Harvester	17	#	6,283,427	1,549,191	8.76%
In-Field Buggy	59	#	2,153,500	340,933	1.93%
Transport Trucks	142	#	15,052,000	2,434,897	13.77%
High-Energy Sorghum Trailers	142	#	7,369,800	837,222	4.73%
Switchgrass Trailers	23	#	805,000	100,342	0.57%
Support Vehicles	30	#	1,050,000	250,598	1.42%
Storage Handling	44	#	5,413,100	728,970	4.12%
Disc	11	#	494,958	136,899	0.77%
Bedder	16	#	318,400	34,163	0.19%
Fertilizer Toolbar	9	#	135,000	24,045	0.14%
Cultivator	3	#	283,500	67,084	0.38%
Sprayer	2	#	453,256	79,564	0.45%
Hay Cutter	7	#	811,041	190,779	1.08%
Wheel Rake	4	#	86,500	25,665	0.15%
Square Baler	9	#	872,721	149,034	0.84%
Hipper	13	#	310,765	55,350	0.31%
Rolling Cultivator	5	#	151,450	42,866	0.24%
Land Plane	10	#	395,000	106,067	0.60%
Bale Wagon	17	#	2,472,344	526,268	2.98%
Hay Squeeze	14	#	1,911,350	393,414	2.22%
Irrigation					
Develop Irrigation Well Size 2	89	#	23,514,913	1,898,035	10.73%
Re-Lift Pump	284	#	4,899,000	467,480	2.64%
SG Custom Establishment					
SG Harvest Production	36,676	acres	10,940,386	804,820	4.55%
SG Insurance Production	40,000	acres	11,932,000	877,767	4.96%
Storage					
Storage Land	7,127,040	sq ft	1,425,408	221,959	1.26%
Purchase Storage	174	#	18,548,400	1,704,210	9.64%
Silo Cover	4,134,240	sq ft	1,033,560	272,120	1.54%
Total Cost			$137,050,314	$17,682,598	100%

Table E84. Sensitivity Scenario 5K (Periodic Storage Losses are Set at 5%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$1,111,260	2.49%
Land				
HES Land	acres	42,598	2,449,385	5.48%
SG Production Land	acres	36,677	825,233	1.85%
SG Insurance Land	acres	40,000	700,000	1.57%
Labor				
Hire Full-Time Labor	persons	220	10,764,050	24.10%
Hire Part-Time Labor	hours	32,520	438,744	0.98%
Irrigation				
Pump Groundwater	acre-inches	710,097	3,975,192	8.90%
HES Field Operations				
Disc	n/a	n/a	149,652	0.34%
Disc	n/a	n/a	149,652	0.34%
Land Plane	n/a	n/a	250,129	0.56%
Bed	n/a	n/a	79,181	0.18%
Hip Beds	n/a	n/a	81,952	0.18%
Fertilize	n/a	n/a	8,076,828	18.08%
Hip Beds	n/a	n/a	81,952	0.18%
Spray	n/a	n/a	510,139	1.14%
Condition Beds	n/a	n/a	84,639	0.19%
Always Planting	n/a	n/a	1,699,014	3.80%
Cultivate	n/a	n/a	94,790	0.21%
Always Harvesting	n/a	n/a	2,307,230	5.17%
Support Vehicles	n/a	n/a	28,769	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,355,216	7.51%
Transportation				
Transport HES	wet ton	1,120,729	2,661,635	0.79%
Transport SG	dry tons	100,000	353,171	
Transfer Tractor Hours				0.16%
Transfer Tractor Hours 225 hp to 152 hp	hours	7,019	70,409	0.15%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,595	65,778	
Overhead Management				9.64%
Overhead Management	persons	46	4,305,467	100%
Total cost			$44,669,500	100%

Table E85. Summary of Sensitivity Scenario 5K (Periodic Storage Losses are Set at 5%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$17,682,598	$223.05	$44.21	$0.5894	28.36%
Annual Operating Costs	44,669,500	563.48	111.67	1.4890	71.64%
Total Cost	$62,352,097	$786.53	$155.88	$2.0784	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E86. Critical Results for Sensitivity Scenario 5L (Periodic Storage Losses are Set at 0.2%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5L[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,553	(292)	(0.79%)
Acres of SG	37,225	38,145	920	2.47%
Total farm acres[d]	187,760	187,804	44	0.02%
HES Dry Ton Production	313,266	303,269	(9,997)	(3.19%)
HES Wet Ton Production	950,719	927,980	(22,739)	(2.39%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.30	(0.20)	(2.39%)
Average SG Dry Ton Yield per Acre	2.69	2.62	(0.07)	(2.54%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$51,804,859	($1,797,344)	(3.35%)
Cost per Acre of All Biomass feedstock Produced	723.67	693.52	(30.15)	(4.17%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	129.51	(4.50)	(3.36%)
Cost per Gallon of Fuel	1.7867	1.7268	(0.0599)	(3.35%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$112,809,226	($5,440,069)	(4.60%)
Annualized Investment Costs	14,919,357	13,895,447	(1,023,910)	(6.86%)
Percent of All Costs	27.8%	26.8%	(1.0%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	186.02	(15.40)	(7.64%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	34.74	(2.56)	(6.87%)
Cost per Gallon of Fuel	0.4973	0.4632	(0.0341)	(6.86%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$37,909,411	($773,434)	(2.00%)
Percent of All Costs	72.2%	73.2%	1.0%	--
Cost per Acre of All Biomass feedstock Produced	522.25	507.50	(14.75)	(2.82%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	94.77	(1.94)	(2.00%)
Cost per Gallon of Fuel	1.2894	1.2636	(0.0258)	(2.00%)

[a] In this scenario, periodic storage losses are set at 0.2 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E87. Sensitivity Scenario 5L (Periodic Storage Losses are Set at 0.2%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	209,520	sq ft	$96,379	$25,951	0.19%
Office Space	7,470	sq ft	1,120,500	196,890	1.42%
Pole Barns	77,598	sq ft	1,086,372	190,893	1.37%
Inside Machinery Storage	23,427	sq ft	2,811,240	493,981	3.55%
Headquarters Land	216,990	sq ft	24,737	2,164	0.02%
Purchased Machinery					
Tractor Size 1	18	#	3,106,080	594,691	4.28%
Tractor Size 2	38	#	5,017,900	819,151	5.90%
Tractor Size 3	0	#	0	0	0.00%
Planter	7	#	461,188	264,065	1.90%
Harvester	11	#	4,065,747	1,002,418	7.21%
In-Field Buggy	46	#	1,679,000	265,812	1.91%
Transport Trucks	109	#	11,554,000	1,869,040	13.45%
High-Energy Sorghum Trailers	109	#	5,657,100	642,656	4.62%
Switchgrass Trailers	12	#	420,000	52,352	0.38%
Support Vehicles	26	#	910,000	217,185	1.56%
Storage Handling	32	#	3,936,800	530,160	3.82%
Disc	7	#	314,973	87,118	0.63%
Bedder	10	#	199,000	21,352	0.15%
Fertilizer Toolbar	8	#	120,000	21,373	0.15%
Cultivator	3	#	283,500	67,084	0.48%
Sprayer	2	#	453,256	79,564	0.57%
Hay Cutter	4	#	463,452	109,017	0.78%
Wheel Rake	3	#	64,875	19,249	0.14%
Square Baler	5	#	484,845	82,797	0.60%
Hipper	11	#	262,955	46,835	0.34%
Rolling Cultivator	4	#	121,160	34,293	0.25%
Land Plane	8	#	316,000	84,854	0.61%
Bale Wagon	9	#	1,308,888	278,613	2.01%
Hay Squeeze	7	#	955,675	196,707	1.42%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	11.97%
Re-Lift Pump	244	#	4,209,000	401,638	2.89%
SG Custom Establishment					
SG Harvest Production	38,145	acres	11,378,621	837,058	6.02%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.32%
Storage					
Storage Land	5,898,240	sq ft	1,179,648	183,690	1.32%
Purchase Storage	144	#	15,350,400	1,410,380	10.15%
Silo Cover	3,421,440	sq ft	855,360	225,203	1.62%
Total Cost			$112,809,226	$13,895,447	100%

Table E88. Sensitivity Scenario 5L (Periodic Storage Losses are Set at 0.2%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$943,030	2.49%
Land				
HES Land	acres	36,553	2,101,798	5.54%
SG Production Land	acres	38,145	858,263	2.26%
SG Insurance Land	acres	40,000	700,000	1.85%
Labor				
Hire Full-Time Labor	persons	160	7,828,400	20.65%
Hire Part-Time Labor	hours	38,251	516,067	1.36%
Irrigation				
Pump Groundwater	acre-inches	609,339	3,411,134	9.00%
HES Field Operations				
Disc	n/a	n/a	128,417	0.34%
Disc	n/a	n/a	128,417	0.34%
Land Plane	n/a	n/a	214,637	0.57%
Bed	n/a	n/a	67,946	0.18%
Hip Beds	n/a	n/a	70,323	0.19%
Fertilize	n/a	n/a	6,930,771	18.28%
Hip Beds	n/a	n/a	70,323	0.19%
Spray	n/a	n/a	437,753	1.15%
Condition Beds	n/a	n/a	72,629	0.19%
Always Planting	n/a	n/a	1,457,934	3.85%
Cultivate	n/a	n/a	81,340	0.21%
Always Harvesting	n/a	n/a	1,950,726	5.15%
Support Vehicles	n/a	n/a	24,687	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,462,797	9.13%
Transportation				
Transport HES	wet ton	927,980	2,197,905	5.80%
Transport SG	dry tons	100,000	353,171	0.93%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	4,124	41,371	0.11%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,980	68,413	0.18%
Overhead Management				
Overhead Management	persons	45	3,791,132	10.00%
Total cost			$37,909,411	100%

Table E89. Summary of Sensitivity Scenario 5L (Periodic Storage Losses are Set at 0.2%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$13,895,447	$186.02	$34.74	$0.4632	26.82%
Annual Operating Costs	37,909,411	507.50	94.77	1.2636	73.18%
Total Cost	$51,804,859	$693.52	$129.51	$1.7268	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E90. Critical Results for Sensitivity Scenario 6A (Trafficable Days Set at 50%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	33,714	(3,131)	(8.50%)
Acres of SG	37,225	36,173	(1,052)	(2.83%)
Total farm acres[d]	187,760	177,315	(10,445)	(5.56)
HES Dry Ton Production	313,266	313,119	(147)	(0.05%)
HES Wet Ton Production	950,719	941,757	(8,962)	(0.94%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	9.29	0.79	9.26%
Average SG Dry Ton Yield per Acre	2.69	2.76	0.07	2.77%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$45,694,255	($7,907,948)	(14.75%)
Cost per Acre of All Biomass feedstock Produced	723.67	653.83	(69.84)	(9.65%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	114.24	(19.77)	(14.76%)
Cost per Gallon of Fuel	1.7867	1.5231	(0.2636)	(14.75%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$98,605,424	($19,643,871)	(16.61%)
Annualized Investment Costs	14,919,357	11,744,825	(3,174,532)	(21.28%)
Percent of All Costs	27.8%	25.7%	(2.1%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	168.05	(33.37)	(16.57%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	29.36	(7.94)	(21.28%)
Cost per Gallon of Fuel	0.4973	0.3915	(0.1058)	(21.28%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$33,949,430	($4,733,415)	(12.24%)
Percent of All Costs	72.2%	74.3%	2.1%	--
Cost per Acre of All Biomass feedstock Produced	522.25	485.78	(36.47)	(6.98%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	84.87	(11.84)	(12.24%)
Cost per Gallon of Fuel	1.2894	1.1316	(0.1578)	(12.24%)

[a] In this scenario, trafficable days are set at 50 percent probability. This is the only variable changed from the Year 2 Baseline Scenario.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E91. Sensitivity Scenario 6A (Trafficable Days Set at 50%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	153,381	sq ft	$ 70,555	$ 18,998	0.16%
Office Space	6,989	sq ft	1,048,350	184,212	1.57%
Pole Barns	55,196	sq ft	772,744	135,784	1.16%
Inside Machinery Storage	18,000	sq ft	2,160,000	379,547	3.23%
Headquarters Land	160,370	sq ft	18,282	1,599	0.01%
Purchased Machinery					
Tractor Size 1	10	#	1,725,600	330,384	2.81%
Tractor Size 2	31	#	4,093,550	668,255	5.69%
Planter	4	#	263,536	150,894	1.28%
Harvester	9	#	3,326,520	820,160	6.98%
In-Field Buggy	32	#	1,168,000	184,913	1.57%
Transport Trucks	78	#	8,268,000	1,337,478	11.39%
High-Energy Sorghum Trailers	78	#	4,048,200	459,883	3.92%
Switchgrass Trailers	15	#	525,000	65,440	0.56%
Support Vehicles	10	#	350,000	83,533	0.71%
Storage Handling	24	#	2,952,600	397,620	3.39%
Disc	6	#	269,977	74,672	0.64%
Bedder	5	#	99,500	10,676	0.09%
Fertilizer Toolbar	5	#	75,000	13,358	0.11%
Cultivator	2	#	189,000	44,722	0.38%
Sprayer	1	#	226,628	39,782	0.34%
Hay Cutter	5	#	579,315	136,271	1.16%
Wheel Rake	3	#	64,875	19,249	0.16%
Square Baler	6	#	581,814	99,356	0.85%
Hipper	6	#	143,430	25,546	0.22%
Rolling Cultivator	3	#	90,870	25,720	0.22%
Land Plane	5	#	197,500	53,034	0.45%
Bale Wagon	11	#	1,599,752	340,526	2.90%
Hay Squeeze	9	#	1,228,725	252,909	2.15%
Irrigation					
Develop Irrigation Well Size 2	64	#	16,909,600	1,364,879	11.62%
Re-Lift Pump		#			
SG Custom Establishment	225		3,881,250	370,362	3.15%
SG Harvest Production	36,173	acres	10,790,326	793,781	6.76%
SG Insurance Production	40,000	acres	11,932,000	877,767	7.47%
Storage					
Storage Land	6,430,720	sq ft	1,286,144	200,274	1.71%
Purchase Storage	157	#	16,736,200	1,537,706	13.09%
Silo Cover	3,730,320	sq ft	932,580	245,534	2.09%
Total Cost			98,605,424	11,744,825	100.00%

Table E92. Sensitivity Scenario 6A (Trafficable Days Set at 50%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 844,483	2.49%
Land				
HES Land	acres	33,714	1,938,555	5.71%
SG Production Land	acres	36,173	813,893	2.40%
SG Insurance Land	acres	40,000	700,000	2.06%
Labor				
Hire Full-Time Labor	persons	120	5,871,300	17.29%
Hire Part-Time Labor	hours	29,982	404,497	1.19%
Irrigation				
Pump Groundwater	acre-inches	561,997	3,146,109	9.27%
HES Field Operations				
Disc	n/a	n/a	118,440	0.35%
Disc	n/a	n/a	118,440	0.35%
Land Plane	n/a	n/a	197,961	0.58%
Bed	n/a	n/a	62,667	0.18%
Hip Beds	n/a	n/a	64,860	0.19%
Fertilize	n/a	n/a	6,392,292	18.83%
Hip Beds	n/a	n/a	64,860	0.19%
Spray	n/a	n/a	403,742	1.19%
Condition Beds	n/a	n/a	66,986	0.20%
Always Planting	n/a	n/a	1,344,661	3.96%
Cultivate	n/a	n/a	75,020	0.22%
Always Harvesting	n/a	n/a	1,873,321	5.52%
Support Vehicles	n/a	n/a	22,769	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,318,378.31	9.77%
Transportation				
Transport HES	wet tons	941,757	2,237,222	6.59%
Transport SG	dry tons	100,000	353,171	1.04%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	265	2,660	0.01%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,464	64,876	0.19%
Overhead Management				
Overhead Management	persons	41	3,448,242	10.16%
Total Cost			$33,949,431	100.00%

Table E93. Summary of Sensitivity Scenario 6A (Trafficable Days Set at 50%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$11,744,825	$168.05	$ 29.36	$0.391	25.70%
Annual Operating Costs	33,949,430	485.78	84.87	1.132	74.30%
Total Cost	$45,694,255	$653.83	$114.24	$1.523	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E94. Critical Results for Sensitivity Scenario 6B (Trafficable Days Set at 90%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	41,240	4,395	11.93%
Acres of SG	37,225	38,780	1,555	4.18%
Total farm acres[d]	187,760	202,500	147,40	7.85%
HES Dry Ton Production	313,266	317,016	3,750	1.20%
HES Wet Ton Production	950,719	964,530	138,11	1.45%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	7.69	(0.81)	(9.56%)
Average SG Dry Ton Yield per Acre	2.69	2.58	(0.11)	(4.14%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	67,745,155	$14,142,952	26.39%
Cost per Acre of All Biomass feedstock Produced	723.67	846.60	122.93	16.99%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	169.36	35.35	26.38%
Cost per Gallon of Fuel	1.7867	2.2582	0.4715	26.39%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$153,016,603	$34,767,308	29.40%
Annualized Investment Costs	14,919,357	20,981,396	6,062,039	40.63%
Percent of All Costs	27.8%	31.0%	3.2%	--
Cost per Acre of All Biomass feedstock Produced	201.42	262.20	60.78	30.18%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	52.45	15.15	40.63%
Cost per Gallon of Fuel	0.4973	0.6994	0.2021	40.64%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$46,763,759	$8,080,914	20.89%
Percent of All Costs	72.2%	69.03%	(3.2%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	584.40	62.15	11.90%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	116.91	20.20	20.89%
Cost per Gallon of Fuel	1.2894	1.5588	0.2694	20.89%

[a] In this scenario, trafficable days are set at 90 percent probability.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E95. Sensitivity Scenario 6B (Trafficable Days Set at 90%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	389,628	sq ft	$ 179,229	$ 48,260	0.23%
Office Space	8,002	sq ft	1,200,300	210,912	1.01%
Pole Barns	145,317	sq ft	2,034,438	357,484	1.70%
Inside Machinery Storage	45,496	sq ft	5,459,520	959,326	4.57%
Headquarters Land	397,630	sq ft	45,330	3,966	0.02%
Purchased Machinery					
Tractor Size 1	38	#	6,557,280	1,255,460	5.98%
Tractor Size 2	69	#	9,111,450	1,487,406	7.09%
Planter	18	#	1,185,912	679,025	3.24%
Harvester	20	#	7,392,267	1,822,578	8.69%
In-Field Buggy	75	#	2,737,500	433,390	2.07%
Transport Trucks	190	#	20,140,000	3,257,960	15.53%
High-Energy Sorghum Trailers	190	#	9,861,000	1,120,227	5.34%
Switchgrass Trailers	20	#	700,000	87,254	0.42%
Support Vehicles	60	#	2,100,000	501,196	2.39%
Storage Handling	57	#	7,012,425	944,348	4.50%
Disc	15	#	674,943	186,680	0.89%
Bedder	19	#	378,100	40,569	0.19%
Fertilizer Toolbar	17	#	255,000	45,418	0.22%
Cultivator	4	#	378,000	89,445	0.43%
Sprayer	3	#	679,884	119,347	0.57%
Hay Cutter	7	#	811,041	190,779	0.91%
Wheel Rake	4	#	86,500	25,665	0.12%
Square Baler	8	#	775,752	132,474	0.63%
Hipper	23	#	549,815	97,927	0.47%
Rolling Cultivator	8	#	242,320	68,586	0.33%
Land Plane	19	#	750,500	201,528	0.96%
Bale Wagon	15	#	2,181,480	464,354	2.21%
Hay Squeeze	12	#	1,638,300	337,212	1.61%
Irrigation					
Develop Irrigation Well Size 2	82	#	21,665,425	1,748,752	8.33%
Re-Lift Pump		#			
SG Custom Establishment	275		4,743,750	452,665	2.16%
SG Harvest Production	38,780	acres	11,568,074	850,995	4.06%
SG Insurance Production	40,000	acres	11,932,000	877,767	4.18%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	0.91%
Purchase Storage	149	#	15,883,400	1,459,352	6.96%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.11%
Total Cost			$153,016,603	$20,981,396	100.00%

Table E96. Sensitivity Scenario 6B (Trafficable Days Set at 90%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 1,163,377	2.49%
Land				
HES Land	acres	41,240	2,371,300	5.07%
SG Production Land	acres	38,780	872,550	1.87%
SG Insurance Land	acres	40,000	700,000	1.50%
Labor				
Hire Full-Time Labor	persons	270	13,210,425	28.25%
Hire Part-Time Labor	hours	41,676	562,267	1.20%
Irrigation				
Pump Groundwater	acre-inches	687,470	3,848,523	8.23%
HES Field Operations				
Disc	n/a	n/a	144,883	0.31%
Disc	n/a	n/a	144,883	0.31%
Land Plane	n/a	n/a	242,158	0.52%
Bed	n/a	n/a	76,658	0.16%
Hip Beds	n/a	n/a	79,340	0.17%
Fertilize	n/a	n/a	7,819,462	16.72%
Hip Beds	n/a	n/a	79,340	0.17%
Spray	n/a	n/a	493,883	1.06%
Condition Beds	n/a	n/a	81,942	0.18%
Always Planting	n/a	n/a	1,644,876	3.52%
Cultivate	n/a	n/a	91,769	0.20%
Always Harvesting	n/a	n/a	2,129,669	4.55%
Support Vehicles	n/a	n/a	27,852	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,509,306	7.50%
Transportation				
Transport HES	wet tons	964,530	2,288,341	4.89%
Transport SG	dry tons	100,000	353,171	0.76%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	2,404	24,117	0.05%
Transfer Tractor Hours 152 hp to 100 hp	hours	10,146	69,552	0.15%
Overhead Management				
Overhead Management	persons	56	4,734,080	10.12%
Total Cost			$46,763,759	100.00%

Table E97. Summary of Sensitivity Scenario 6B (Trafficable Days Set at 90%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$20,981,396	$262.20	$ 52.45	$0.699	30.97%
Annual Operating Costs	46,763,759	584.40	116.91	1.559	69.03%
Total Cost	$67,745,155	$846.60	$169.36	$2.258	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E98. Critical Results for Sensitivity Scenario 6C (Only SG is Produced and Trafficable Days are Set at 90%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6C[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	0	(36,845)	(100.00%)
Acres of SG	37,225	145,780	108,555	291.62%
Total farm acres[d]	187,760	185,780	(1,980)	(1.05%)
HES Dry Ton Production	313,266	0	(313,266)	(100.00%)
HES Wet Ton Production	950,719	0	(950,719)	(100.00%)
SG Dry Ton Production	100,000	404,504	304,504	305.50%
Average HES Dry Ton Yield per Acre	8.50	0.00	(8.50)	(100.00%)
Average SG Dry Ton Yield per Acre	2.69	2.77	0.08	3.15%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$41,023,607	($12,578,596)	(23.47%)
Cost per Acre of All Biomass feedstock Produced	723.67	281.41	(442.26)	(61.11%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	102.56	(31.45)	(23.47%)
Cost per Gallon of Fuel	1.7867	1.3675	(0.4192)	(23.46%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$96,757,700	($21,491,595)	(18.17%)
Annualized Investment Costs	14,919,357	11,122,206	(3,797,151)	(25.45%)
Percent of All Costs	27.8%	27.1%	(0.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	76.29	(125.13)	(62.12%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	27.81	(9.49)	(25.45%)
Cost per Gallon of Fuel	0.4973	0.3707	(0.1266)	(25.45%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$29,901,400	($8,781,445)	(22.70%)
Percent of All Costs	72.2%	72.89%	0.7%	--
Cost per Acre of All Biomass feedstock Produced	522.25	205.11	(317.14)	(60.73%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	74.75	(21.96)	(22.70%)
Cost per Gallon of Fuel	1.2894	0.9967	(0.2927)	(22.70%)

[a] In this scenario, SG is the only biomass feedstock produced and supplied to the conversion facility and trafficable days are set at 90 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E99. Sensitivity Scenario 6C (Only SG is Produced and Trafficable Days are Set at 90%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	131,402	sq ft	$ 60,445	$ 16,276	0.15%
Office Space	14,578	sq ft	2,186,700	384,239	3.45%
Pole Barns	41,401	sq ft	579,614	101,848	0.92%
Inside Machinery Storage	17,011	sq ft	2,041,320	358,693	3.23%
Headquarters Land	145,980	sq ft	16,642	1,456	0.01%
Purchased Machinery					
Tractor Size 1	0	#	0.00	0.00	0.00%
Tractor Size 2	0	#	0.00	0.00	0.00%
Tractor Size 3	30	#	2,048,940	442,502	3.98%
Planter	0	#	0.00	0.00	0.00%
Harvester	0	#	0.00	0.00	0.00%
In-Field Buggy	0	#	0.00	0.00	0.00%
Transport Trucks	60	#	6,360,000	1,028,830	9.25%
High-Energy Sorghum Trailers	0	#	0.00	0.00	0.00%
Switchgrass Trailers	60	#	2,100,000	261,761	2.35%
Support Vehicles	0	#	0.00	0.00	0.00%
Storage Handling	0	#	0.00	0.00	0.00%
Disc	0	#	0.00	0.00	0.00%
Bedder	0	#	0.00	0.00	0.00%
Fertilizer Toolbar	0	#	0.00	0.00	0.00%
Cultivator	0	#	0.00	0.00	0.00%
Sprayer	6	#	1,359,768	238,693	2.15%
Hay Cutter	18	#	2,085,534	490,576	4.41%
Wheel Rake	10	#	216,250	64,162	0.58%
Square Baler	21	#	2,036,349	347,745	3.13%
Hipper	0	#	0.00	0.00	0.00%
Rolling Cultivator	0	#	0.00	0.00	0.00%
Land Plane	0	#	0.00	0.00	0.00%
Bale Wagon	44	#	6,399,008	1,362,106	12.25%
Hay Squeeze	36	#	4,914,900	1,011,636	9.10%
Irrigation					
Develop Irrigation Well Size 2	0	#	0.00	0.00	0.00%
Re-Lift Pump		#			
SG Custom Establishment	0		0.00	0.00	0.00%
SG Harvest Production	145,780	acres	43,486,062	3,199,014	28.76%
SG Insurance Production	40,000	acres	11,932,000	877,767	7.89%
Storage					
Storage Land	3,031,040	sq ft	606,208	94,396	0.85%
Purchase Storage	74	#	7,888,400	724,779	6.52%
Silo Cover	1,758,240	sq ft	439,560	115,729	1.04%
Total Cost			$96,757,700	$11,122,206	100.00%

Table E100. Sensitivity Scenario 6C (Only SG is Produced and Trafficable Days are Set at 90%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$ 743,745	2.49%
Land				
HES Land	acres	0	0	0.00%
SG Production Land	acres	145,780	3,280,050	10.97%
SG Insurance Land	acres	40,000	700,000	2.34%
Labor				
Hire Full-Time Labor	persons	130	6,360,575	21.27%
Hire Part-Time Labor	hours	33,806	456,087	1.53%
Irrigation				
Pump Groundwater	acre-inches	0	0	0.00%
HES Field Operations				
Disc	n/a	n/a	0	0.00%
Disc	n/a	n/a	0	0.00%
Land Plane	n/a	n/a	0	0.00%
Bed	n/a	n/a	0	0.00%
Hip Beds	n/a	n/a	0	0.00%
Fertilize	n/a	n/a	0	0.00%
Hip Beds	n/a	n/a	0	0.00%
Spray	n/a	n/a	0	0.00%
Condition Beds	n/a	n/a	0	0.00%
Always Planting	n/a	n/a	0	0.00%
Cultivate	n/a	n/a	0	0.00%
Always Harvesting	n/a	n/a	0	0.00%
Support Vehicles	n/a	n/a	0	0.00%
SG Field Operations				
Grow and Harvest	n/a	n/a	13,383,388	44.76%
Transportation				
Transport HES	wet tons	0	15,000	0.05%
Transport SG	dry tons	404,504	1,428,591	4.78%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	0	0	0.00%
Transfer Tractor Hours 152 hp to 100 hp	hours	0	0	0.00%
Overhead Management				
Overhead Management	persons	42	3,533,965	11.82%
Total Cost			$29,901,400	100.00%

Table E101. Summary of Sensitivity Scenario 6C (Only SG is Produced and Trafficable Days are Set at 90%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$11,122,206	$ 76.29	$27.81	$0.371	27.11%
Annual Operating Costs	29,901,400	205.11	74.75	0.997	72.89%
Total Cost	$41,023,607	$281.41	$102.56	$1.367	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E102. Critical Results for Sensitivity Scenario 6D (Trafficable Day are Set at 75 Percent Probability and Multiplied by 10 Times), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6D[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	35,810	(1,035)	(2.81%)
Acres of SG	37,225	36,600	(625)	(1.68%)
Total farm acres[d]	187,760	184,030	(3,730)	(1.99%)
HES Dry Ton Production	313,266	311,939	(1,327)	(0.42%)
HES Wet Ton Production	950,719	938,985	(11,734)	(1.23%)
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.71	0.21	2.48%
Average SG Dry Ton Yield per Acre	2.69	2.73	0.04	1.57%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$44,938,826	($8,663,377)	(16.16%)
Cost per Acre of All Biomass feedstock Produced	723.67	620.62	(103.05)	(14.24%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	112.35	(21.66)	(16.17%)
Cost per Gallon of Fuel	1.7867	1.4980	(0.2887)	(16.16%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$72,108,680	($46,140,615)	(39.02%)
Annualized Investment Costs	14,919,357	7,006,940	(7,912,417)	(53.03%)
Percent of All Costs	27.8%	15.6%	(12.2%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	96.77	(104.65)	(51.96%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	17.52	(19.78)	(53.04%)
Cost per Gallon of Fuel	0.4973	0.2336	(0.2637)	(53.03%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$37,931,886	($750,959)	(1.94%)
Percent of All Costs	72.2%	84.41%	12.2%	--
Cost per Acre of All Biomass feedstock Produced	522.25	523.85	1.60	0.31%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	94.83	(1.88)	(1.94%)
Cost per Gallon of Fuel	1.2894	1.2644	(0.0250)	(1.94%)

[a] In this scenario, trafficable days are set at 75 percent probability and multiplied by 10 times. The intent is eliminated/minimize the effects of considering the effects of field trafficability.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E103. Sensitivity Scenario 6D (Trafficable Days are Set at 75 Percent Probability and Multiplied by 10 Times) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	42,903	sq ft	$ 19,735	$ 5,314	0.08%
Office Space	7,245	sq ft	1,086,750	190,960	2.73%
Pole Barns	13,313	sq ft	186,382	32,750	0.47%
Inside Machinery Storage	4,506	sq ft	540,720	95,013	1.36%
Headquarters Land	50,148	sq ft	5,717	500	0.01%
Purchased Machinery					
Tractor Size 1	5	#	862,800	165,192	2.36%
Tractor Size 2	4	#	528,200	86,226	1.23%
Tractor Size 3	1	#	68,298	14,750	0.21%
Planter	1	#	65,884	37,724	0.54%
Harvester	2	#	739,227	182,258	2.60%
In-Field Buggy	5	#	182,500	28,893	0.41%
Transport Trucks	12	#	1,272,000	205,766	2.94%
High-Energy Sorghum Trailers	12	#	622,800	70,751	1.01%
Switchgrass Trailers	3	#	105,000	13,088	0.19%
Support Vehicles	3	#	105,000	25,060	0.36%
Storage Handling	4	#	492,100	66,270	0.95%
Disc	3	#	134,989	37,336	0.53%
Bedder	2	#	39,800	4,270	0.06%
Fertilizer Toolbar	1	#	15,000	2,672	0.04%
Cultivator	1	#	94,500	22,361	0.32%
Sprayer	1	#	226,628	39,782	0.57%
Hay Cutter	1	#	115,863	27,254	0.39%
Wheel Rake	1	#	21,625	6,416	0.09%
Square Baler	1	#	96,969	16,559	0.24%
Hipper	1	#	23,905	4,258	0.06%
Rolling Cultivator	1	#	30,290	8,573	0.12%
Land Plane	3	#	118,500	31,820	0.45%
Bale Wagon	2	#	290,864	61,914	0.88%
Hay Squeeze	2	#	273,050	56,202	0.80%
Irrigation					
Develop Irrigation Well Size 2	72	#	19,023,300	1,535,489	21.91%
Re-Lift Pump		#			
SG Custom Establishment	239		4,122,750	393,407	5.61%
SG Harvest Production	36,600	acres	10,917,780	803,157	11.46%
SG Insurance Production	40,001	acres	11,932,150	877,778	12.53%
Storage					
Storage Land	6,021,120	sq ft	1,204,224	187,517	2.68%
Purchase Storage	147	#	15,670,200	1,439,763	20.55%
Silo Cover	3,492,720	sq ft	873,180	229,894	3.28%
Total Cost			$72,108,680	$7,006,940	100.00%

Table E104. Sensitivity Scenario 6D (Trafficable Days are Set at 75 Percent Probability and Multiplied by 10 Times) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$943,589	2.49%
Land				
HES Land	acres	35,810	2,059,075	5.43%
SG Production Land	acres	36,600	823,500	2.17%
SG Insurance Land	acres	40,001	700,009	1.85%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.93%
Hire Part-Time Labor	hours	33,292	449,155	1.18%
Irrigation				
Pump Groundwater	acre-inches	596,948	3,341,773	8.81%
HES Field Operations				
Disc	n/a	n/a	125,806	0.33%
Disc	n/a	n/a	125,806	0.33%
Land Plane	n/a	n/a	210,272	0.55%
Bed	n/a	n/a	66,564	0.18%
Hip Beds	n/a	n/a	68,893	0.18%
Fertilize	n/a	n/a	6,789,842	17.90%
Hip Beds	n/a	n/a	68,893	0.18%
Spray	n/a	n/a	428,851	1.13%
Condition Beds	n/a	n/a	71,152	0.19%
Always Planting	n/a	n/a	1,428,288	3.77%
Cultivate	n/a	n/a	79,686	0.21%
Always Harvesting	n/a	n/a	1,936,858	5.11%
Support Vehicles	n/a	n/a	24,185	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,349,667	8.83%
Transportation				
Transport HES	wet tons	938,985	2,231,540	5.88%
Transport SG	dry tons	100,000	353,171	0.93%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	4,967	49,824	0.13%
Transfer Tractor Hours 152 hp to 100 hp	hours	1,594	10,927	0.03%
Overhead Management				
Overhead Management	persons	46	$3,876,855	10.22%
Total Cost			$37,931,886	100.00%

Table E105. Summary of Sensitivity Scenario 6D (Trafficable Days are Set at 75 Percent Probability and Multiplied by 10 Times), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$ 7,006,940	$ 96.77	$ 17.52	$0.234	15.59%
Annual Operating Costs	37,931,886	523.85	94.83	1.264	84.41%
Total Cost	$44,938,826	$620.62	$112.35	$1.498	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E106. Critical Results for Sensitivity Scenario 6E (Economics of Farm Size), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity 6E Results – One Single Farm[a]	Sensitivity 6E Results – All Single Farms[a]	Change	% Change[b,c]
Production Level					
Acre of HES	36,845	2,496	46,437	9,592	26.0%
Acres of SG	37,225	0	0	(37,225)	(100.00%)
Total farm acres[d]	187,760	7,488	139,312	(48,448)	(25.8%)
HES Dry Ton Production	313,266	22,990	426,046	112,781	36.0%
HES Wet Ton Production	950,719	68,660	1,277,395	326,676	34.4%
SG Dry Ton Production	100,000	0	0	(100,000)	(100.00%)
Average HES Dry Ton Yield per Acre	8.50	9.21	9.21	0.71	8.36%
Average SG Dry Ton Yield per Acre	2.69	0.00	0.00	(2.69)	(100.00%)
Total Capital Investments and Operating Costs					
Annual Cost	$53,602,203	$5,622,749	$104,609,300	$51,007,097	95.2%
Cost per Acre of All Biomass feedstock Produced	723.67	2,252.70	2,252.70	1,529.03	211.29%
Cost per Dry Ton of All Biomass feedstock Produced	134.01	261.52	261.52	127.51	95.15%
Cost per Gallon of Fuel	1.7867	3.4870	3.4870	1.7003	95.16%
Capital Investment Costs					
Total Purchase Costs	$118,249,295	$7,583,371	$141,086,000	$22,836,680	19.3%
Annualized Investment Costs	14,919,357	1,072,424	19,952,070	5,032,717	33.7%
Percent of All Costs	27.8%	19.1%	19.1%	(8.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	429.66	429.66	228.24	113.31%
Cost per Dry Ton of All Biomass feedstock Produced	37.30	49.88	49.88	12.58	33.73%
Cost per Gallon of Fuel	0.4973	0.6651	0.6651	0.1678	33.74%

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Table E106, Continued.

Item	Year 2 Baseline Results	Sensitivity Scenario 6E Results – One Single Farm[a]	Sensitivity Scenario 6E Results – All Single Farms[a]	Change	% Change[b,c]
Annual Operating Costs					
Total Annual Operating Costs	$38,682,845	$4,550,325	$84,657,210	$45,974,360	118.85%
Percent of All Costs	72.2%	80.9%	80.9%	8.7%	--
Cost per Acre of All Biomass feedstock Produced	522.25	1,823.05	1,823.05	1,300.80	249.08%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	211.64	211.64	114.93	118.84%
Cost per Gallon of Fuel	1.2894	2.8219	2.8219	1.5325	118.85%

[a] In this scenario, economies of farm size is evaluated for a 2,496 acre farm. No SG is produced and no SG for insurance is established. Dividing the 30-million conversion facility's annual requirements of 400,000 dry tons of biomass feedstock by 21,500 (assumed production for a single farm), 18.60 single commercial farms are required to supply the CBFFE.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E107. Sensitivity Scenario 6E (Economics of Farm Size) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	20,210	sq ft	9,297	2,503	0.23%
Office Space	250	sq ft	37,500	6,589	0.61%
Pole Barns	7,580	sq ft	106,120	18,647	1.74%
Inside Machinery Storage	2,400	sq ft	288,000	50,606	4.72%
Headquarters Land	20,460	sq ft	2,332	204	0.02%
Purchased Machinery					
Tractor Size 1	2	#	345,120	66,077	6.16%
Tractor Size 2	3	#	396,150	64,670	6.03%
Tractor Size 3	0	#	0.00	0.00	0.00%
Planter	1	#	65,884	37,724	3.52%
Harvester	1	#	369,613	91,129	8.50%
In-Field Buggy	4	#	146,000	23,114	2.16%
Transport Trucks	10	#	1,060,000	171,472	15.99%
High-Energy Sorghum Trailers	10	#	519,000	58,959	5.50%
Switchgrass Trailers	0	#	0.00	0.00	0.00%
Support Vehicles	2	#	70,000	16,707	1.56%
Storage Handling	3	#	369,075	49,703	4.63%
Disc	1	#	44,996	12,445	1.16%
Bedder	1	#	19,900	2,135	0.20%
Fertilizer Toolbar	1	#	15,000	2,672	0.25%
Cultivator	1	#	94,500	22,361	2.09%
Sprayer	1	#	226,628	39,782	3.71%
Hay Cutter	0	#	0.00	0.00	0.00%
Wheel Rake	0	#	0.00	0.00	0.00%
Square Baler	0	#	0.00	0.00	0.00%
Hipper	1	#	23,905	4,258	0.40%
Rolling Cultivator	1	#	30,290	8,573	0.80%
Land Plane	1	#	39,500	10,607	0.99%
Bale Wagon	0	#	0.00	0.00	0.00%
Hay Squeeze	0	#	0.00	0.00	0.00%
Irrigation					
Develop Irrigation Well Size 2	5	#	1,321,063	106,631	9.94%
Re-Lift Pump	17	#	293,250	27,983	2.61%
SG Custom Establishment					
SG Harvest Production	0	acres	0.00	0.00	0.00%
SG Insurance Production	0	acres	0.00	0.00	0.00%
Storage					
Storage Land	573,440	sq ft	114,688	17,859	1.67%
Purchase Storage	14	#	1,492,400	137,120	12.79%
Silo Cover	332,640	sq ft	83,160	21,895	2.04%
Total Cost			$7,583,371	$1,072,424	100.00%

Table E108. Sensitivity Scenario 6E (Economics of Farm Size) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$112,865	2.48%
Land				
HES Land	acres	2,496	143,520	3.15%
SG Production Land	acres	0	0.00	0.00%
SG Insurance Land	acres	0	0.00	0.00%
Labor				
Hire Full-Time Labor	persons	10	489,275	10.75%
Hire Part-Time Labor	hours	6,274	84,645	1.86%
Irrigation				
Pump Groundwater	acre-inches	41,595	232,855	5.12%
HES Field Operations				
Disc	n/a	n/a	8,766	0.19%
Disc	n/a	n/a	8,766	0.19%
Land Plane	n/a	n/a	14,652	0.32%
Bed	n/a	n/a	4,638	0.10%
Hip Beds	n/a	n/a	4,800	0.11%
Fertilize	n/a	n/a	473,117	10.40%
Hip Beds	n/a	n/a	4,800	0.11%
Spray	n/a	n/a	29,882	0.66%
Condition Beds	n/a	n/a	4,958	0.11%
Always Planting	n/a	n/a	99,523	2.19%
Cultivate	n/a	n/a	5,553	0.12%
Always Harvesting	n/a	n/a	137,751	3.03%
Support Vehicles	n/a	n/a	1,685	0.04%
SG Field Operations				
Grow and Harvest	n/a	n/a	0.00	0.00%
Transportation				
Transport HES	wet tons	68,660	177,300	3.90%
Transport SG	dry tons	0	0.00	0.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	566	5,675	0.12%
Transfer Tractor Hours 152 hp to 100 hp	hours	0	0.00	0.00%
Overhead Management				
Overhead Management	persons	30	2,505,295	55.06%
Total Cost			$4,550,325	100.00%

Table E109. Summary of Sensitivity Scenario 6E (Economics of Farm Size), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$1,072,424	$429.66	$49.88	$0.6651	19.07%
Annual Operating Costs	4,550,325	1,823.05	211.64	2.8219	80.93%
Total Cost	$5,622,749	$2,252.70	$261.52	$3.4870	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E110. Critical Results for Sensitivity Scenario 6F (Maximum HES Moisture Content Set at 25%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6F[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	35,168	(1,677)	(4.55%)
Acres of SG	37,225	36,810	(415)	(1.11%)
Total farm acres[d]	187,760	182,314	(5,446)	(2.90%)
HES Dry Ton Production	313,266	315,901	2,635	0.84%
HES Wet Ton Production	950,719	358,021	(592,698)	(62.34%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.98	0.48	5.68%
Average SG Dry Ton Yield per Acre	2.69	2.72	0.03	0.99%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$46,413,710	($7,188,493)	(13.41%)
Cost per Acre of All Biomass feedstock Produced	723.67	644.83	(78.84)	(10.89%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	116.03	(17.98)	(13.41%)
Cost per Gallon of Fuel	1.7867	1.5471	(0.2396)	(13.41%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$104,374,846	($13,874,449)	(11.73%)
Annualized Investment Costs	14,919,357	12,826,164	(2,093,193)	(14.03%)
Percent of All Costs	27.8%	27.6%	(0.2%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	178.20	(23.22)	(11.53%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	32.07	(5.23)	(14.03%)
Cost per Gallon of Fuel	0.4973	0.4275	(0.0698)	(14.03%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$33,587,547	($5,095,298)	(13.17%)
Percent of All Costs	72.2%	72.4%	0.2%	--
Cost per Acre of All Biomass feedstock Produced	522.25	466.64	(55.61)	(10.65%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	83.97	(12.74)	(13.17%)
Cost per Gallon of Fuel	1.2894	1.1196	(0.1698)	(13.17%)

[a] In this scenario, HES harvest moisture content is reduced to 25 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E111. Sensitivity Scenario 6F (Maximum HES Moisture Content Set at 25%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	192,374	sq ft	$88,492	$23,828	0.19%
Office Space	7,198	sq ft	1,079,700	189,721	1.48%
Pole Barns	70,627	sq ft	988,778	173,744	1.35%
Inside Machinery Storage	21,961	sq ft	2,635,320	463,069	3.61%
Headquarters Land	199,572	sq ft	22,751	1,990	0.02%
Purchased Machinery					
Tractor Size 1	19	#	3,278,640	627,730	4.89%
Tractor Size 2	30	#	3,961,500	646,698	5.04%
Planter	6	#	395,304	226,342	1.76%
Harvester	11	#	4,065,747	1,002,418	7.82%
In-Field Buggy	38	#	1,387,000	219,584	1.71%
Transport Trucks	74	#	7,844,000	1,268,890	9.89%
High-Energy Sorghum Trailers	74	#	3,840,600	436,299	3.40%
Switchgrass Trailers	17	#	595,000	74,166	0.58%
Support Vehicles	25	#	875,000	208,832	1.63%
Storage Handling	29	#	3,567,725	480,458	3.75%
Disc	8	#	359,970	99,563	0.78%
Bedder	12	#	238,800	25,622	0.20%
Fertilizer Toolbar	8	#	120,000	21,373	0.17%
Cultivator	2	#	189,000	44,722	0.35%
Sprayer	1	#	226,628	39,782	0.31%
Hay Cutter	5	#	579,315	136,271	1.06%
Wheel Rake	3	#	64,875	19,249	0.15%
Square Baler	6	#	581,814	99,356	0.77%
Hipper	13	#	310,765	55,350	0.43%
Rolling Cultivator	3	#	90,870	25,720	0.20%
Land Plane	7	#	276,500	74,247	0.58%
Bale Wagon	12	#	1,745,184	371,483	2.90%
Hay Squeeze	10	#	1,365,250	281,010	2.19%
Irrigation					
Develop Irrigation Well Size 2	66	#	17,438,025	1,407,532	10.97%
Re-Lift Pump		#			
SG Custom Establishment	235		4,053,750	386,823	3.02%
SG Harvest Production	36,809	acres	10,980,155	807,745	6.30%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.84%
Storage					
Storage Land	6,512,640	sq ft	1,302,528	202,825	1.58%
Purchase Storage	159	#	16,949,400	1,557,295	12.14%
Silo Cover	3,777,840	sq ft	944,460	248,661	1.94%
Total Cost			$104,374,846	$12,826,164	100%

Table E112. Sensitivity Scenario 6F (Maximum HES Moisture Content Set at 25%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$835,477	2.49%
Land				
HES Land	acres	35,168	2,022,160	6.02%
SG Production Land	acres	36,810	828,225	2.47%
SG Insurance Land	acres	40,000	700,000	2.08%
Labor				
Hire Full-Time Labor	persons	120	5,871,300	17.48%
Hire Part-Time Labor	hours	31,299	422,266	1.26%
Irrigation				
Pump Groundwater	acre-inches	586,251	3,281,885	9.77%
HES Field Operations				
Disc	n/a	n/a	123,551	0.37%
Disc	n/a	n/a	123,551	0.37%
Land Plane	n/a	n/a	206,504	0.61%
Bed	n/a	n/a	65,371	0.19%
Hip Beds	n/a	n/a	67,659	0.20%
Fertilize	n/a	n/a	6,668,163	19.85%
Hip Beds	n/a	n/a	67,659	0.20%
Spray	n/a	n/a	421,166	1.25%
Condition Beds	n/a	n/a	69,877	0.21%
Always Planting	n/a	n/a	1,402,692	4.18%
Cultivate	n/a	n/a	78,258	0.23%
Always Harvesting	n/a	n/a	1,600,500	4.77%
Support Vehicles	n/a	n/a	23,751	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,364,979	10.02%
Transportation				
Transport HES	wet tons	358,021	1,439,446	4.29%
Transport SG	dry tons	100,000	353,171	1.05%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,553	35,645	0.11%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,630	66,017	0.20%
Overhead Management				
Overhead Management	persons	41	3,448,242	10.27%
Total Cost			$33,587,547	100%

Table E113. Summary of Sensitivity Scenario 6F (Maximum HES Moisture Content Set at 25%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$12,826,164	$178.20	$ 32.07	$0.428	27.63%
Annual Operating Costs	33,587,547	466.64	83.97	1.120	72.37%
Total Cost	$46,413,710	$644.83	$116.03	$1.547	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E114. Critical Results for Sensitivity Scenario 6G (HES Semi Trailer Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 6G[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,678	(167)	(0.45%)
Acres of SG	37,225	37,480	255	0.69%
Total farm acres[d]	187,760	187,514	(246)	(0.13%)
HES Dry Ton Production	313,266	314,801	1,535	0.49%
HES Wet Ton Production	950,719	959,860	9,141	0.96%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.58	0.08	0.97%
Average SG Dry Ton Yield per Acre	2.69	2.67	(0.02)	(0.81%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$51,852,619	(1,749,584)	(3.26%)
Cost per Acre of All Biomass feedstock Produced	723.67	699.22	(24.45)	(3.38%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	129.63	(4.38)	(3.27%)
Cost per Gallon of Fuel	1.7867	1.7284	(0.06)	(3.26%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$113,483,079	(4,766,216)	(4.03%)
Annualized Investment Costs	14,919,357	14,170,458	(748,899)	(5.02%)
Percent of All Costs	27.8%	27.3%	(0.00)	--
Cost per Acre of All Biomass feedstock Produced	201.42	191.08	(10.34)	(5.13%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	35.43	(1.87)	(5.02%)
Cost per Gallon of Fuel	0.4973	0.4723	(0.02)	(5.02%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$37,682,161	(1,000,684)	(2.59%)
Percent of All Costs	72.2%	72.7%	0.00	--
Cost per Acre of All Biomass feedstock Produced	522.25	508.13	(14.12)	(2.70%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	94.21	(2.50)	(2.59%)
Cost per Gallon of Fuel	1.2894	1.2561	(0.03)	(2.58%)

[a] In this scenario, HES semi trailer capacity is increased by 20 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E115. Sensitivity Scenario 6G (HES Semi Trailer Capacity is Increased by 20%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	221,526	sq ft	$101,902	$27,438	0.19%
Office Space	7,416	sq ft	1,112,400	195,467	1.38%
Pole Barns	82,034	sq ft	1,148,476	201,806	1.42%
Inside Machinery Storage	24,878	sq ft	2,985,360	524,576	3.70%
Headquarters Land	228,942	sq ft	26,099	2,283	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	4.90%
Tractor Size 2	39	#	5,149,950	840,707	5.93%
Planter	7	#	461,188	264,065	1.86%
Harvester	11	#	4,065,747	1,002,418	7.07%
In-Field Buggy	50	#	1,825,000	288,926	2.04%
Transport Trucks	101	#	10,706,000	1,731,863	12.22%
High-Energy Sorghum Trailers	101	#	5,241,900	595,489	4.20%
Switchgrass Trailers	17	#	595,000	74,166	0.52%
Support Vehicles	26	#	910,000	217,185	1.53%
Storage Handling	36	#	4,428,900	596,430	4.21%
Disc	7	#	314,973	87,118	0.61%
Bedder	10	#	199,000	21,352	0.15%
Fertilizer Toolbar	8	#	120,000	21,373	0.15%
Cultivator	3	#	283,500	67,084	0.47%
Sprayer	2	#	453,256	79,564	0.56%
Hay Cutter	5	#	579,315	136,271	0.96%
Wheel Rake	3	#	64,875	19,249	0.14%
Square Baler	6	#	581,814	99,356	0.70%
Hipper	11	#	262,955	46,835	0.33%
Rolling Cultivator	4	#	121,160	34,293	0.24%
Land Plane	10	#	395,000	106,067	0.75%
Bale Wagon	12	#	1,745,184	371,483	2.62%
Hay Squeeze	10	#	1,365,250	281,010	1.98%
Irrigation					
Develop Irrigation Well Size 2	73	#	19,287,513	1,556,815	10.99%
Re-Lift Pump		#			
SG Custom Establishment	245		4,226,250	403,284	2.85%
SG Harvest Production	37,480	acres	11,180,284	822,468	5.80%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.19%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.34%
Purchase Storage	149	#	15,883,400	1,459,352	10.30%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.64%
Total Cost			$113,483,079	$14,170,458	100%

Table E116. Sensitivity Scenario 6G (HES Semi Trailer Capacity is Increased by 20%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$937,375	2.49%
Land				
HES Land	acres	36,678	2,108,985	5.60%
SG Production Land	acres	37,480	843,300	2.24%
SG Insurance Land	acres	40,000	700,000	1.86%
Labor				
Hire Full-Time Labor	persons	160	7,828,400	20.77%
Hire Part-Time Labor	hours	35,619	480,548	1.28%
Irrigation				
Pump Groundwater	acre-inches	608,703	3,407,575	9.04%
HES Field Operations				
Disc	n/a	n/a	128,283	0.34%
Disc	n/a	n/a	128,283	0.34%
Land Plane	n/a	n/a	214,413	0.57%
Bed	n/a	n/a	67,875	0.18%
Hip Beds	n/a	n/a	70,250	0.19%
Fertilize	n/a	n/a	6,923,540	18.37%
Hip Beds	n/a	n/a	70,250	0.19%
Spray	n/a	n/a	437,296	1.16%
Condition Beds	n/a	n/a	72,553	0.19%
Always Planting	n/a	n/a	1,456,413	3.86%
Cultivate	n/a	n/a	81,255	0.22%
Always Harvesting	n/a	n/a	1,977,056	5.25%
Support Vehicles	n/a	n/a	24,661	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,414,108	9.06%
Transportation				
Transport HES	wet tons	959,860	2,030,529	5.39%
Transport SG	dry tons	100,000	353,171	0.94%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	6,745	67,661	0.18%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,806	67,221	0.18%
Overhead Management				
Overhead Management	persons	45	3,791,132	10.06%
Total Cost			$37,682,161	100%

Table E117. Summary of Sensitivity Scenario 6G (HES Semi Trailer Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$14,170,458	$191.08	$35.43	$0.472	27.33%
Annual Operating Costs	37,682,161	508.13	94.21	1.256	72.67%
Total Cost	$51,852,619	$699.22	$129.63	$1.728	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E118. Critical Results for Sensitivity Scenario 7A (HES Maximum-Expected Yields are Set at 10 Dry Ton with no Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 7A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	40,199	3,354	9.10%
Acres of SG	37,225	36,601	(624)	(1.68%)
Total farm acres[d]	187,760	197,198	9,438	5.03%
HES Dry Ton Production	313,266	311,926	(1,340)	(0.43%)
HES Wet Ton Production	950,719	946,564	(4,155)	(0.44%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	7.76	(0.74)	(8.71%)
Average SG Dry Ton Yield per Acre	2.69	2.73	0.04	1.57%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$40,472,986	($13,129.217)	(24.49%)
Cost per Acre of All Biomass feedstock Produced	723.67	526.99	(196.68)	(27.18%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	101.18	(32.83)	(24.50%)
Cost per Gallon of Fuel	1.7867	1.3491	(0.4376)	(24.49%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$66,289,848	($51,959,447)	(4394%)
Annualized Investment Costs	14,919,357	8,635,603	(6,283,754)	(42.12%)
Percent of All Costs	27.8%	21.3%	(6.5%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	112.44	(88.98)	(44.17%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	21.59	(15.71)	(42.12%)
Cost per Gallon of Fuel	0.4973	0.2879	(0.2094)	(42.12%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$31,837,383	($6,845,462)	(17.70%)
Percent of All Costs	72.2%	78.7%	6.5%	--
Cost per Acre of All Biomass feedstock Produced	522.25	414.55	(107.70)	(20.62%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	79.59	(17.12)	(17.70%)
Cost per Gallon of Fuel	1.2894	1.0612	(0.2282)	(17.69%)

[a] In this scenario, HES maximum-expected yields are set at 10 dry ton with no irrigation, capital costs are reduced by 15 percent, and trafficable days are set at 50 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E119. Sensitivity Scenario 7A (HES Maximum-Expected Yields are Set at 10 Dry Ton with no Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	164,572	sq ft	$64,348	$17,326	0.20%
Office Space	7,680	sq ft	979,200	172,061	1.99%
Pole Barns	59,435	sq ft	707,277	124,280	1.44%
Inside Machinery Storage	19,011	sq ft	1,939,122	340,735	3.95%
Headquarters Land	172,252	sq ft	16,691	1,460	0.02%
Purchased Machinery					
Tractor Size 1	13	#	1,906,788	365,074	4.23%
Tractor Size 2	28	#	3,142,790	513,047	5.94%
Tractor Size 3	0	#	0	0	0.00%
Planter	6	#	336,008	192,390	2.23%
Harvester	9	#	2,827,542	697,136	8.07%
In-Field Buggy	33	#	1,023,825	162,088	1.88%
Transport Trucks	77	#	6,937,700	1,122,282	13.00%
High-Energy Sorghum Trailers	77	#	3,396,855	385,889	4.47%
Switchgrass Trailers	16	#	476,000	59,332	0.69%
Support Vehicles	12	#	357,000	85,203	0.99%
Storage Handling	24	#	2,509,710	337,977	3.91%
Disc	7	#	267,727	74,050	0.86%
Bedder	8	#	135,320	14,519	0.17%
Fertilizer Toolbar	6	#	76,500	13,625	0.16%
Cultivator	2	#	160,650	38,014	0.44%
Sprayer	1	#	192,634	33,815	0.39%
Hay Cutter	5	#	492,418	115,830	1.34%
Wheel Rake	3	#	55,144	16,361	0.19%
Square Baler	6	#	494,542	84,452	0.98%
Hipper	8	#	162,554	28,952	0.34%
Rolling Cultivator	3	#	77,240	21,862	0.25%
Land Plane	5	#	167,875	45,079	0.52%
Bale Wagon	12	#	1,483,406	315,761	3.66%
Hay Squeeze	10	#	1,160,463	238,858	2.77%
Irrigation					
Develop Irrigation Well Size 2	0	#	0	0	0.00%
Re-Lift Pump	0	#	0	0	0.00%
SG Custom Establishment					
SG Harvest Production	36,601	acres	9,280,367	682,702	7.91%
SG Insurance Production	40,000	acres	10,142,200	746,102	8.64%
Storage					
Storage Land	6,062,080	sq ft	1,030,554	160,474	1.86%
Purchase Storage	148	#	13,410,280	1,232,124	14.27%
Silo Cover	3,516,480	sq ft	879,120	196,740	2.28%
Total Cost			$66,289,848	$8,635,603	100.00%

Table E120. Sensitivity Scenario 7A (HES Maximum-Expected Yields are Set at 10 Dry Ton with no Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$791,923	2.49%
Land				
HES Land	acres	40,199	2,311,443	7.26%
SG Production Land	acres	36,601	823,523	2.59%
SG Insurance Land	acres	40,000	700,000	2.20%
Labor				
Hire Full-Time Labor	persons	120	5,871,300	18.44%
Hire Part-Time Labor	hours	27,413	369,843	1.16%
Irrigation				
Pump Groundwater	acre-inches	0	0	0.00%
HES Field Operations				
Disc	n/a	n/a	141,224	0.44%
Disc	n/a	n/a	141,224	0.44%
Land Plane	n/a	n/a	236,042	0.74%
Bed	n/a	n/a	74,722	0.23%
Hip Beds	n/a	n/a	77,337	0.24%
Fertilize	n/a	n/a	6,367,779	20.00%
Hip Beds	n/a	n/a	77,337	0.24%
Spray	n/a	n/a	481,409	1.51%
Condition Beds	n/a	n/a	79,873	0.25%
Always Planting	n/a	n/a	1,603,332	5.04%
Cultivate	n/a	n/a	89,452	0.28%
Always Harvesting	n/a	n/a	2,081,403	6.54%
Support Vehicles	n/a	n/a	27,149	0.09%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,349,740	10.52%
Transportation				
Transport HES	wet ton	946,564	2,244,125	7.05%
Transport SG	dry tons	100,000	353,171	1.11%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,002	30,116	0.09%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,576	65,644	0.21%
Overhead Management				
Overhead Management	persons	41	3,448,242	10.83%
Total cost			$31,837,383	100.00%

Table E121. Summary of Sensitivity Scenario 7A (HES Maximum-Expected Yields are Set at 10 Dry Ton with no Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%),Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$8,635,603	$112.44	$21.59	$0.2879	21.34%
Annual Operating Costs	31,837,383	414.55	79.59	1.0612	78.66%
Total Cost	$40,472,986	$526.99	$101.18	$1.3491	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E122. Critical Results for Sensitivity Scenario 7B (HES Maximum-Expected Yields are Set at 12 Dry Tons with Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 7B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	33,425	(3,420)	(9.28%)
Acres of SG	37,225	35,591	(1,634)	(4.39%)
Total farm acres[d]	187,760	175,866	(11,894)	(6.33%)
HES Dry Ton Production	313,266	313,377	111	0.04%
HES Wet Ton Production	950,719	942,235	(8,484)	(0.89%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	9.38	0.88	10.30%
Average SG Dry Ton Yield per Acre	2.69	2.81	0.12	4.45%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$43,914,252	($9,687,951)	(18.07%)
Cost per Acre of All Biomass feedstock Produced	723.67	636.29	(87.38)	(12.07%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	109.79	(24.22)	(18.08%)
Cost per Gallon of Fuel	1.7867	1.4638	(0.3229)	(18.07%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$84,683,232	($33,566,063)	(28.39%)
Annualized Investment Costs	14,919,357	10,113,284	(4,806,073)	(32.21%)
Percent of All Costs	27.8%	23.0%	(4.8%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	146.54	(54.88)	(27.25%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	25.28	(12.02)	(32.22%)
Cost per Gallon of Fuel	0.4973	0.3371	(0.1602)	(32.21%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$33,800,967	($4,881,878)	(12.62%)
Percent of All Costs	72.2%	77.0%	4.8%	--
Cost per Acre of All Biomass feedstock Produced	522.25	489.76	(32.49)	(6.22%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	84.50	(12.21)	(12.62%)
Cost per Gallon of Fuel	1.2894	1.1267	(0.1627)	(12.62%)

[a] In this scenario, HES maximum-expected yields are set at 12 dry ton with no irrigation, capital costs are reduced by 15 percent, and trafficable days are set at 50 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E123. Sensitivity Scenario 7B (HES Maximum-Expected Yields are Set at 12 Dry Tons with Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	157,870	sq ft	$61,727	$16,621	0.16%
Office Space	6,902	sq ft	880,005	154,631	1.53%
Pole Barns	57,330	sq ft	682,227	119,878	1.19%
Inside Machinery Storage	18,154	sq ft	1,851,708	325,375	3.22%
Headquarters Land	164,772	sq ft	15,966	1,397	0.01%
Purchased Machinery					
Tractor Size 1	13	#	1,906,788	365,074	3.61%
Tractor Size 2	28	#	3,142,790	513,047	5.07%
Tractor Size 3	0	#	0	0	0.00%
Planter	4	#	224,006	128,260	1.27%
Harvester	9	#	2,827,542	697,136	6.89%
In-Field Buggy	33	#	1,023,825	162,088	1.60%
Transport Trucks	79	#	7,117,900	1,151,432	11.39%
High-Energy Sorghum Trailers	79	#	3,485,085	395,912	3.91%
Switchgrass Trailers	16	#	476,000	59,332	0.59%
Support Vehicles	10	#	297,500	71,003	0.70%
Storage Handling	24	#	2,509,710	337,977	3.34%
Disc	6	#	229,481	63,471	0.63%
Bedder	8	#	135,320	14,519	0.14%
Fertilizer Toolbar	5	#	63,750	11,354	0.11%
Cultivator	2	#	160,650	38,014	0.38%
Sprayer	1	#	192,634	33,815	0.33%
Hay Cutter	5	#	492,418	115,830	1.15%
Wheel Rake	3	#	55,144	16,361	0.16%
Square Baler	6	#	494,542	84,452	0.84%
Hipper	6	#	121,916	21,714	0.21%
Rolling Cultivator	2	#	51,493	14,574	0.14%
Land Plane	5	#	167,875	45,079	0.45%
Bale Wagon	12	#	1,483,406	315,761	3.12%
Hay Squeeze	10	#	1,160,463	238,858	2.36%
Irrigation					
Develop Irrigation Well Size 2	64	#	14,373,160	1,160,147	11.47%
Re-Lift Pump	223	#	3,269,738	312,010	3.09%
SG Custom Establishment					
SG Harvest Production	35,591	acres	9,024,153	663,854	6.56%
SG Insurance Production	40,000	acres	10,142,200	746,102	7.38%
Storage					
Storage Land	6,553,600	sq ft	1,114,112	173,485	1.72%
Purchase Storage	160	#	14,497,600	1,332,026	13.17%
Silo Cover	3,801,600	sq ft	950,400	212,691	2.10%
Total Cost			$84,683,232	$10,113,284	100.00%

Table E124. Sensitivity Scenario 7B (HES Maximum-Expected Yields are Set at 12 Dry Tons with Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$840,788	2.49%
Land				
HES Land	acres	33,425	1,921,938	5.69%
SG Production Land	acres	35,591	800,798	2.37%
SG Insurance Land	acres	40,000	700,000	2.07%
Labor				
Hire Full-Time Labor	persons	120	5,871,300	17.37%
Hire Part-Time Labor	hours	30,545	412,095	1.22%
Irrigation				
Pump Groundwater	acre-inches	557,190	3,119,199	9.23%
HES Field Operations				
Disc	n/a	n/a	117,427	0.35%
Disc	n/a	n/a	117,427	0.35%
Land Plane	n/a	n/a	196,267	0.58%
Bed	n/a	n/a	62,131	0.18%
Hip Beds	n/a	n/a	64,305	0.19%
Fertilize	n/a	n/a	6,337,615	18.75%
Hip Beds	n/a	n/a	64,305	0.19%
Spray	n/a	n/a	400,289	1.18%
Condition Beds	n/a	n/a	66,413	0.20%
Always Planting	n/a	n/a	1,333,159	3.94%
Cultivate	n/a	n/a	74,378	0.22%
Always Harvesting	n/a	n/a	1,864,667	5.52%
Support Vehicles	n/a	n/a	22,574	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,275,743	9.69%
Transportation				
Transport HES	wet ton	942,235	2,238,433	6.62%
Transport SG	dry tons	100,000	353,171	1.04%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,434	34,445	0.10%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,311	63,832	0.19%
Overhead Management				
Overhead Management	persons	41	3,448,242	10.20%
Total cost			$33,800,967	100.00%

Table E125. Summary of Sensitivity Scenario 7B (HES Maximum-Expected Yields are Set at 12 Dry Tons with Irrigation, Capital Costs are Reduced by 15%, and Trafficable Days are Set at 50%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$10,113,284	$146.54	$25.28	$0.3371	23.03%
Annual Operating Costs	33,800,967	489.76	84.50	1.1267	76.97%
Total Cost	$43,914,252	$636.29	$109.79	$1.4638	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E126. Critical Results for Sensitivity Scenario 7C (HES Maximum-Expected Yields are Set at 18 Dry Tons with Irrigation, Capital Costs are Reduced by 15 Percent, and Trafficable Days are Set at 50 Percent), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 7C[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	22,383	(14,462)	(39.25%)
Acres of SG	37,225	36,525	(700)	(1.88%)
Total farm acres[d]	187,760	143,674	(44,086)	(23.48%)
HES Dry Ton Production	313,266	311,746	(1,520)	(0.49%)
HES Wet Ton Production	950,719	939,250	(11,469)	(1.21%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	13.93	5.43	63.86%
Average SG Dry Ton Yield per Acre	2.69	2.74	0.05	1.78%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$39,428,245	($14,173,958)	(26.44%)
Cost per Acre of All Biomass feedstock Produced	723.67	669.32	(54.35)	(7.51%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	98.57	(35.44)	(26.45%)
Cost per Gallon of Fuel	1.7867	1.3143	(0.4724)	(26.44%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$78,049,534	($40,199,761)	(34.00%)
Annualized Investment Costs	14,919,357	9,098,474	(5,820,883)	(39.02%)
Percent of All Costs	27.8%	23.1%	(4.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	154.45	(46.97)	(23.32%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	22.75	(14.55)	(39.02%)
Cost per Gallon of Fuel	0.4973	0.3033	(0.1940)	(39.01%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$30,329,771	($8,353,074)	(21.59%)
Percent of All Costs	72.2%	76.9%	4.7%	--
Cost per Acre of All Biomass feedstock Produced	522.25	514.87	(7.38)	(1.41%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	75.82	(20.89)	(21.60%)
Cost per Gallon of Fuel	1.2894	1.0110	(0.2784)	(21.59%)

[a] In this scenario, HES maximum-expected yields are set at 18 dry ton with no irrigation, capital costs are reduced by 15 percent, and trafficable days are set at 50 percent.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E127. Sensitivity Scenario 7C (HES Maximum-expected Yields are Set at 18 Dry Tons with Irrigation, Capital Costs are Reduced by 15 Percent, and Trafficable Days are Set at 50 Percent) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	131,691	sq ft	$51,491	$13,865	0.15%
Office Space	5,891	sq ft	751,103	131,981	1.45%
Pole Barns	47,934	sq ft	570,415	100,231	1.10%
Inside Machinery Storage	14,966	sq ft	1,526,532	268,236	2.95%
Headquarters Land	137,582	sq ft	13,332	1,166	0.01%
Purchased Machinery					
Tractor Size 1	7	#	1,026,732	196,579	2.16%
Tractor Size 2	27	#	3,030,548	494,724	5.44%
Tractor Size 3	0	#	0	0	0.00%
Planter	4	#	224,006	128,260	1.41%
Harvester	6	#	1,885,028	464,757	5.11%
In-Field Buggy	29	#	899,725	142,441	1.57%
Transport Trucks	75	#	6,757,500	1,093,131	12.01%
High-Energy Sorghum Trailers	75	#	3,308,625	375,866	4.13%
Switchgrass Trailers	16	#	476,000	59,332	0.65%
Support Vehicles	7	#	208,250	49,702	0.55%
Storage Handling	24	#	2,509,710	337,977	3.71%
Disc	3	#	114,740	31,736	0.35%
Bedder	4	#	67,660	7,260	0.08%
Fertilizer Toolbar	3	#	38,250	6,813	0.07%
Cultivator	1	#	80,325	19,007	0.21%
Sprayer	1	#	192,634	33,815	0.37%
Hay Cutter	5	#	492,418	115,830	1.27%
Wheel Rake	3	#	55,144	16,361	0.18%
Square Baler	6	#	494,542	84,452	0.93%
Hipper	4	#	81,277	14,476	0.16%
Rolling Cultivator	2	#	51,493	14,574	0.16%
Land Plane	3	#	100,725	27,047	0.30%
Bale Wagon	12	#	1,483,406	315,761	3.47%
Hay Squeeze	10	#	1,160,463	238,858	2.63%
Irrigation					
Develop Irrigation Well Size 2	60	#	13,474,838	1,087,638	11.95%
Re-Lift Pump	150	#	2,199,375	209,872	2.31%
SG Custom Establishment					
SG Harvest Production	36,525	acres	9,261,096	681,284	7.49%
SG Insurance Production	40,000	acres	10,142,200	746,102	8.20%
Storage					
Storage Land	6,062,080	sq ft	1,030,554	160,474	1.76%
Purchase Storage	148	#	13,410,280	1,232,124	13.54%
Silo Cover	3,516,480	sq ft	879,120	196,740	2.16%
Total Cost			$78,049,534	$9,098,474	100.00%

Table E128. Sensitivity Scenario 7C (HES Maximum-expected Yields are Set at 18 Dry Tons with Irrigation, Capital Costs are Reduced by 15 Percent, and Trafficable Days are Set at 50 Percent) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$754,405	2.49%
Land				
HES Land	acres	22,383	1,287,023	4.24%
SG Production Land	acres	36,525	821,813	2.71%
SG Insurance Land	acres	40,000	700,000	2.31%
Labor				
Hire Full-Time Labor	persons	110	5,382,025	17.75%
Hire Part-Time Labor	hours	28,746	387,824	1.28%
Irrigation				
Pump Groundwater	acre-inches	373,120	2,088,760	6.89%
HES Field Operations				
Disc	n/a	n/a	78,634	0.26%
Disc	n/a	n/a	78,634	0.26%
Land Plane	n/a	n/a	131,430	0.43%
Bed	n/a	n/a	41,606	0.14%
Hip Beds	n/a	n/a	43,061	0.14%
Fertilize	n/a	n/a	6,338,982	20.90%
Hip Beds	n/a	n/a	43,061	0.14%
Spray	n/a	n/a	268,052	0.88%
Condition Beds	n/a	n/a	44,474	0.15%
Always Planting	n/a	n/a	892,745	2.94%
Cultivate	n/a	n/a	49,807	0.16%
Always Harvesting	n/a	n/a	1,514,877	4.99%
Support Vehicles	n/a	n/a	15,117	0.05%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,344,174	11.03%
Transportation				
Transport HES	wet ton	939,250	2,230,730	7.35%
Transport SG	dry tons	100,000	353,171	1.16%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	1,129	11,321	0.04%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,556	65,508	0.22%
Overhead Management				
Overhead Management	persons	40	3,362,520	11.09%
Total cost			$30,329,770.92	100.00%

Table E129. Summary of Sensitivity Scenario 7C (HES Maximum-expected Yields are Set at 18 Dry Tons with Irrigation, Capital Costs are Reduced by 15 Percent, and Trafficable Days are Set at 50 Percent), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$9,098,474	$154.45	$22.75	$0.3033	23.08%
Annual Operating Costs	30,329,771	514.87	75.82	1.0110	76.92%
Total Cost	$39,428,245	$669.32	$98.57	$1.3143	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E130. Critical Results for Sensitivity Scenario 8A (HES Maximum-expected Yields are Set at 10 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 8A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	39,806	2,961	8.04%
Acres of SG	37,225	36,485	(740)	(1.99%)
Total farm acres[d]	187,760	195,903	8,143	4.34%
HES Dry Ton Production	313,266	312,275	(991)	(0.32%)
HES Wet Ton Production	950,719	951,406	687	0.07%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	7.84	(0.66)	(7.71%)
Average SG Dry Ton Yield per Acre	2.69	2.74	0.05	1.89%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$34,728,204	($18,873,999)	(35.21%)
Cost per Acre of All Biomass feedstock Produced	723.67	455.21	(268.46)	(37.10%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	86.82	(47.19)	(35.21%)
Cost per Gallon of Fuel	1.7867	1.1576	(0.6291)	(35.21%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$64,672,086	($53,577,209)	(45.31%)
Annualized Investment Costs	14,919,357	8,359,314	(6,560,043)	(43.97%)
Percent of All Costs	27.8%	24.1%	(3.7%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	109.57	(91.85)	(45.60%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	20.90	(16.40)	(43.97%)
Cost per Gallon of Fuel	0.4973	0.2786	(0.2187)	(43.97%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$26,368,890	($12,313,955)	(31.83%)
Percent of All Costs	72.2%	75.9%	3.7%	
Cost per Acre of All Biomass feedstock Produced	522.25	345.64	(176.61)	(33.82%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	65.92	(30.79)	(31.84%)
Cost per Gallon of Fuel	1.2894	0.8790	(0.4104)	(31.83%)

[a] In this scenario, HES maximum-expected yields are set at 10 dry tons per acre and no irrigation, both capital and operating costs are reduced by 15%, trafficable days are set at 50%, and transportation capacity is increased by 20%.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E131. Sensitivity Scenario 8A (HES Maximum-expected Yields are Set at 10 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	156,978	sq ft	$61,378	$16,527	0.20%
Office Space	7,630	sq ft	972,825	170,941	2.04%
Pole Barns	55,943	sq ft	665,722	116,978	1.40%
Inside Machinery Storage	18,731	sq ft	1,910,562	335,717	4.02%
Headquarters Land	164,608	sq ft	15,951	1,395	0.02%
Purchased Machinery					
Tractor Size 1	14	#	2,053,464	393,157	4.70%
Tractor Size 2	28	#	3,142,790	513,047	6.14%
Tractor Size 3	0	#	0	0	0.00%
Planter	6	#	336,008	192,390	2.30%
Harvester	8	#	2,513,371	619,676	7.41%
In-Field Buggy	33	#	1,023,825	162,088	1.94%
Transport Trucks	66	#	5,946,600	961,956	11.51%
High-Energy Sorghum Trailers	66	#	2,911,590	330,762	3.96%
Switchgrass Trailers	16	#	476,000	59,332	0.71%
Support Vehicles	12	#	357,000	85,203	1.02%
Storage Handling	24	#	2,509,710	337,977	4.04%
Disc	6	#	229,481	63,471	0.76%
Bedder	8	#	135,320	14,519	0.17%
Fertilizer Toolbar	5	#	63,750	11,354	0.14%
Cultivator	2	#	160,650	38,014	0.45%
Sprayer	1	#	192,634	33,815	0.40%
Hay Cutter	5	#	492,418	115,830	1.39%
Wheel Rake	3	#	55,144	16,361	0.20%
Square Baler	6	#	494,542	84,452	1.01%
Hipper	7	#	142,235	25,333	0.30%
Rolling Cultivator	3	#	77,239	21,862	0.26%
Land Plane	5	#	167,875	45,079	0.54%
Bale Wagon	12	#	1,483,406	315,761	3.78%
Hay Squeeze	10	#	1,160,463	238,858	2.86%
Irrigation					
Develop Irrigation Well Size 2	0	#	0	0	0.00%
Re-Lift Pump	0	#	0	0	0.00%
SG Custom Establishment					
SG Harvest Production	36,485	acres	9,250,954	680,538	8.14%
SG Insurance Production	40,000	acres	10,142,200	746,102	8.93%
Storage					
Storage Land	6,144,000	sq ft	1,044,480	162,642	1.95%
Purchase Storage	150	#	13,591,500	1,248,774	14.94%
Silo Cover	3,564,000	sq ft	891,000	199,398	2.39%
Total Cost			$64,672,086	$8,359,314	100.00%

Table E132. Sensitivity Scenario 8A (HES Maximum-expected Yields are Set at 10 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$655,836	2.49%
Land				
HES Land	acres	39,806	1,945,518	7.38%
SG Production Land	acres	36,485	697,776	2.65%
SG Insurance Land	acres	40,000	565,000	2.14%
Labor				
Hire Full-Time Labor	persons	110	4,574,721	17.35%
Hire Part-Time Labor	hours	26,619	305,260	1.16%
Irrigation				
Pump Groundwater	acre-inches	0	0	0.00%
HES Field Operations				
Disc	n/a	n/a	118,869	0.45%
Disc	n/a	n/a	118,869	0.45%
Land Plane	n/a	n/a	198,677	0.75%
Bed	n/a	n/a	62,893	0.24%
Hip Beds	n/a	n/a	65,094	0.25%
Fertilize	n/a	n/a	5,359,775	20.33%
Hip Beds	n/a	n/a	65,094	0.25%
Spray	n/a	n/a	405,203	1.54%
Condition Beds	n/a	n/a	67,229	0.25%
Always Planting	n/a	n/a	1,349,528	5.12%
Cultivate	n/a	n/a	75,292	0.29%
Always Harvesting	n/a	n/a	1,917,298	7.27%
Support Vehicles	n/a	n/a	22,851	0.09%
SG Field Operations				
Grow and Harvest	n/a	n/a	2,840,059	10.77%
Transportation				
Transport HES	wet ton	951,406	1,712,262	6.49%
Transport SG	dry tons	100,000	300,196	1.14%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,729	31,795	0.12%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,545	55,621	0.21%
Overhead Management				
Overhead Management	persons	40	2,858,142	10.84%
Total cost			$26,368,890	100%

Table E133. Summary of Sensitivity Scenario 8A (HES Maximum-expected Yields are Set at 10 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$8,359,314	$109.57	$20.90	$0.2786	24.07%
Annual Operating Costs	26,368,890	345.64	65.92	0.8790	75.93%
Total Cost	$34,728,204	$455.21	$86.82	$1.1576	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E134. Critical Results for Sensitivity Scenario 8B (HES Maximum-expected Yields are Set at 12 Dry Tons per Acre, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 8B[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	33,134	(3,711)	(10.07%)
Acres of SG	37,225	35,756	(1,469)	(3.95%)
Total farm acres[d]	187,760	175,158	(12,602)	(6.71%)
HES Dry Ton Production	313,266	314,032	766	0.24%
HES Wet Ton Production	950,719	947,409	(3,310)	(0.35%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	9.48	0.98	11.50%
Average SG Dry Ton Yield per Acre	2.69	2.80	0.11	3.97%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$37,823,720	($15,778,483)	(29.44%)
Cost per Acre of All Biomass feedstock Produced	723.67	549.05	(174.62)	(24.13%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	94.56	(39.45)	(29.44%)
Cost per Gallon of Fuel	1.7867	1.2608	(0.5259)	(29.43%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$82,803,884	($35,445,411)	(29.98%)
Annualized Investment Costs	14,919,357	9,767,738	(5,151,619)	(34.53%)
Percent of All Costs	27.8%	25.8%	(2.0%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	141.79	(59.63)	(29.61%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	24.42	(12.88)	(34.53%)
Cost per Gallon of Fuel	0.4973	0.3256	(0.1717)	(34.53%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$28,055,982	($10,626,863)	(27.47%)
Percent of All Costs	72.2%	74.2%	2.0%	--
Cost per Acre of All Biomass feedstock Produced	522.25	407.26	(114.99)	(22.02%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	70.14	(26.57)	(27.47%)
Cost per Gallon of Fuel	1.2894	0.9352	(0.3542)	(27.47%)

[a] In this scenario, HES maximum-expected yields are set at 12 dry tons per acre, both capital and operating costs are reduced by 15%, trafficable days are set at 50%, and transportation capacity is increased by 20%.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E135. Sensitivity Scenario 8B (HES Maximum-expected Yields are Set at 12 Dry Tons per Acre, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	150,881	sq ft	$58,994	$15,885	0.16%
Office Space	6,893	sq ft	878,858	154,430	1.58%
Pole Barns	54,600	sq ft	649,740	114,170	1.17%
Inside Machinery Storage	17,394	sq ft	1,774,188	311,754	3.19%
Headquarters Land	157,774	sq ft	15,288	1,337	0.01%
Purchased Machinery					
Tractor Size 1	12	#	1,760,112	336,992	3.45%
Tractor Size 2	28	#	3,142,790	513,047	5.25%
Tractor Size 3	0	#	0	0	0.00%
Planter	4	#	224,006	128,260	1.31%
Harvester	8	#	2,513,371	619,676	6.34%
In-Field Buggy	34	#	1,054,850	166,999	1.71%
Transport Trucks	68	#	6,126,800	991,106	10.15%
High-Energy Sorghum Trailers	68	#	2,999,820	340,785	3.49%
Switchgrass Trailers	15	#	446,250	55,624	0.57%
Support Vehicles	10	#	297,500	71,003	0.73%
Storage Handling	25	#	2,614,281	352,059	3.60%
Disc	6	#	229,481	63,471	0.65%
Bedder	7	#	118,405	12,704	0.13%
Fertilizer Toolbar	5	#	63,750	11,354	0.12%
Cultivator	2	#	160,650	38,014	0.39%
Sprayer	1	#	192,634	33,815	0.35%
Hay Cutter	5	#	492,418	115,830	1.19%
Wheel Rake	3	#	55,144	16,361	0.17%
Square Baler	6	#	494,542	84,452	0.86%
Hipper	6	#	121,916	21,714	0.22%
Rolling Cultivator	2	#	51,493	14,574	0.15%
Land Plane	5	#	167,875	45,079	0.46%
Bale Wagon	11	#	1,359,789	289,447	2.96%
Hay Squeeze	9	#	1,044,416	214,973	2.20%
Irrigation					
Develop Irrigation Well Size 2	64	#	14,373,160	1,160,147	11.88%
Re-Lift Pump	221	#	3,240,413	309,211	3.17%
SG Custom Establishment					
SG Harvest Production	35,756	acres	9,066,100	666,940	6.83%
SG Insurance Production	40,000	acres	10,142,200	746,102	7.64%
Storage					
Storage Land	6,676,480	sq ft	1,135,002	176,738	1.81%
Purchase Storage	163	#	14,769,430	1,357,001	13.89%
Silo Cover	3,872,880	sq ft	968,220	216,679	2.22%
Total Cost			$82,803,884	$9,767,738	100.00%

Table E136. Sensitivity Scenario 8B (HES Maximum-expected Yields are Set at 12 Dry Tons per Acre, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$697,820	2.49%
Land				
HES Land	acres	33,134	1,619,424	5.77%
SG Production Land	acres	35,756	683,834	2.44%
SG Insurance Land	acres	40,000	565,000	2.01%
Labor				
Hire Full-Time Labor	persons	110	4,574,721	16.31%
Hire Part-Time Labor	hours	28,854	330,892	1.18%
Irrigation				
Pump Groundwater	acre-inches	552,328	2,641,611	9.42%
HES Field Operations				
Disc	n/a	n/a	98,942	0.35%
Disc	n/a	n/a	98,942	0.35%
Land Plane	n/a	n/a	165,372	0.59%
Bed	n/a	n/a	52,350	0.19%
Hip Beds	n/a	n/a	54,182	0.19%
Fertilize	n/a	n/a	5,339,974	19.03%
Hip Beds	n/a	n/a	54,182	0.19%
Spray	n/a	n/a	337,277	1.20%
Condition Beds	n/a	n/a	55,959	0.20%
Always Planting	n/a	n/a	1,123,299	4.00%
Cultivate	n/a	n/a	62,670	0.22%
Always Harvesting	n/a	n/a	1,730,160	6.17%
Support Vehicles	n/a	n/a	19,020	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	2,794,679	9.96%
Transportation				
Transport HES	wet ton	947,409	1,709,224	6.09%
Transport SG	dry tons	100,000	300,196	1.07%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	3,938	33,575	0.12%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,355	54,509	0.19%
Overhead Management				
Overhead Management	persons	40	2,858,142	10.19%
Total cost			$28,055,982	100.00%

Table E137. Summary of Sensitivity Scenario 8B (HES Maximum-expected Yields are Set at 12 Dry Tons per Acre, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$9,767,738	$141.79	$24.42	$0.3256	25.82%
Annual Operating Costs	28,055,982	407.26	70.14	0.9352	74.18%
Total Cost	$37,823,720	$549.05	$94.56	$1.2608	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E138. Critical Results for Sensitivity Scenario 8C (HES Maximum-expected Yields are Set at 18 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 8C[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	22,631	(14,214)	(38.58%)
Acres of SG	37,225	36,815	(410)	(1.10%)
Total farm acres[d]	187,760	144,708	(43,052)	(22.93%)
HES Dry Ton Production	313,266	313,282	16	0.01%
HES Wet Ton Production	950,719	942,894	(7,825)	(0.82%)
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	13.84	5.34	62.86%
Average SG Dry Ton Yield per Acre	2.69	2.72	0.03	0.98%
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$33,899,270	($19,702,933)	(36.76%)
Cost per Acre of All Biomass feedstock Produced	723.67	570.25	(153.42)	(21.20%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	84.75	(49.26)	(36.76%)
Cost per Gallon of Fuel	1.7867	1.1300	(0.6567)	(36.76%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$73,735,786	($44,513,509)	(37.64%)
Annualized Investment Costs	14,919,357	8,551,552	(6,367,805)	(42.68%)
Percent of All Costs	27.8%	25.2%	(2.6%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	143.85	(57.57)	(28.58%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	21.38	(15.92)	(42.68%)
Cost per Gallon of Fuel	0.4973	0.2851	(0.2122)	(42.68%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$25,347,718	($13,335,127)	(34.47%)
Percent of All Costs	72.2%	74.8%	2.6%	--
Cost per Acre of All Biomass feedstock Produced	522.25	426.40	(95.85)	(18.35%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	63.37	(33.34)	(34.47%)
Cost per Gallon of Fuel	1.2894	0.8449	(0.4445)	(34.47%)

[a] In this scenario, HES maximum-expected yields are set at 10 dry tons per acre and no irrigation, both capital and operating costs are reduced by 15%, trafficable days are set at 50%, and transportation capacity is increased by 20%.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E139. Sensitivity Scenario 8C (HES Maximum-expected Yields are Set at 18 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	123,643	sq ft	$48,344	$13,017	0.15%
Office Space	5,945	sq ft	757,988	133,191	1.56%
Pole Barns	44,665	sq ft	531,514	93,396	1.09%
Inside Machinery Storage	14,184	sq ft	1,446,768	254,221	2.97%
Headquarters Land	129,588	sq ft	12,557	1,099	0.01%
Purchased Machinery					
Tractor Size 1	7	#	1,026,732	196,579	2.30%
Tractor Size 2	28	#	3,142,790	513,047	6.00%
Tractor Size 3	0	#	0	0	0.00%
Planter	3	#	168,004	96,195	1.12%
Harvester	6	#	1,885,028	464,757	5.43%
In-Field Buggy	30	#	930,750	147,352	1.72%
Transport Trucks	64	#	5,766,400	932,805	10.91%
High-Energy Sorghum Trailers	64	#	2,823,360	320,739	3.75%
Switchgrass Trailers	14	#	416,500	51,916	0.61%
Support Vehicles	7	#	208,250	49,702	0.58%
Storage Handling	24	#	2,509,710	337,977	3.95%
Disc	3	#	114,740	31,736	0.37%
Bedder	4	#	67,660	7,260	0.08%
Fertilizer Toolbar	3	#	38,250	6,813	0.08%
Cultivator	1	#	80,325	19,007	0.22%
Sprayer	1	#	192,634	33,815	0.40%
Hay Cutter	4	#	393,934	92,664	1.08%
Wheel Rake	3	#	55,144	16,361	0.19%
Square Baler	5	#	412,118	70,377	0.82%
Hipper	4	#	81,277	14,476	0.17%
Rolling Cultivator	2	#	51,493	14,574	0.17%
Land Plane	3	#	100,725	27,047	0.32%
Bale Wagon	10	#	1,236,172	263,134	3.08%
Hay Squeeze	8	#	928,370	191,087	2.23%
Irrigation					
Develop Irrigation Well Size 2	48	#	10,779,870	870,111	10.17%
Re-Lift Pump	151	#	2,214,038	211,271	2.47%
SG Custom Establishment					
SG Harvest Production	36,815	acres	9,334,622	686,693	8.03%
SG Insurance Production	40,000	acres	10,142,200	746,102	8.72%
Storage					
Storage Land	6,266,880	sq ft	1,065,370	165,895	1.94%
Purchase Storage	153	#	13,863,330	1,273,750	14.89%
Silo Cover	3,635,280	sq ft	908,820	203,386	2.38%
Total Cost			$73,735,786	$8,551,552	100.00%

Table E140. Sensitivity Scenario 8C (HES Maximum-expected Yields are Set at 18 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$630,423	2.49%
Land				
HES Land	acres	22,631	1,106,090	4.36%
SG Production Land	acres	36,815	704,087	2.78%
SG Insurance Land	acres	40,000	565,000	2.23%
Labor				
Hire Full-Time Labor	persons	100	4,158,838	16.41%
Hire Part-Time Labor	hours	29,058	333,231	1.31%
Irrigation				
Pump Groundwater	acre-inches	377,257	1,804,302	7.12%
HES Field Operations				
Disc	n/a	n/a	67,580	0.27%
Disc	n/a	n/a	67,580	0.27%
Land Plane	n/a	n/a	112,954	0.45%
Bed	n/a	n/a	35,757	0.14%
Hip Beds	n/a	n/a	37,008	0.15%
Fertilize	n/a	n/a	5,447,882	21.49%
Hip Beds	n/a	n/a	37,008	0.15%
Spray	n/a	n/a	230,370	0.91%
Condition Beds	n/a	n/a	38,222	0.15%
Always Planting	n/a	n/a	767,248	3.03%
Cultivate	n/a	n/a	42,806	0.17%
Always Harvesting	n/a	n/a	1,437,168	5.67%
Support Vehicles	n/a	n/a	12,992	0.05%
SG Field Operations				
Grow and Harvest	n/a	n/a	2,860,598	11.29%
Transportation				
Transport HES	wet ton	942,894	1,702,564	6.72%
Transport SG	dry tons	100,000	300,196	1.18%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	750	6,395	0.03%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,632	56,124	0.22%
Overhead Management				
Overhead Management	persons	39	2,785,278	10.99%
Total cost			$25,347,718	100.00%

Table E141. Summary of Sensitivity Scenario 8C (HES Maximum-expected Yields are Set at 18 Dry Tons per Acre and No Irrigation, Both Capital and Operating Costs are Reduced by 15%, Trafficable Days are Set at 50%, and Transportation Capacity is Increased by 20%), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Biofuel[d]	% of Total Cost
Capital Investment Costs	$8,551,552	$143.85	$21.38	$0.2851	25.23%
Annual Operating Costs	25,347,718	426.40	63.37	0.8449	74.77%
Total Cost	$33,899,270	$570.25	$84.75	$1.300	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E142. Critical Results for Sensitivity Scenario 9A (HES Land Lease Costs are Reduced), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 5A[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	38,653	1,808	4.91%
Acres of SG	37,225	37,796	571	1.53%
Total farm acres[d]	187,760	193,755	5,995	3.19%
HES Dry Ton Production	313,266	314,991	1,725	0.55%
HES Wet Ton Production	950,719	958,709	7,990	0.84%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.15	(0.35)	(4.13%)
Average SG Dry Ton Yield per Acre	2.69	2.65	(0.04)	(1.64%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	49,703,464	(3,898,739)	(7.27%)
Cost per Acre of All Biomass feedstock Produced	723.67	650.15	(73.52)	(10.16%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	124.26	(9.75)	(7.28%)
Cost per Gallon of Ethanol	1.7867	1.6568	(0.1299)	(7.27%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$116,677,139	(1,572,156)	(1.33%)
Annualized Investment Costs	14,919,357	14,633,517	(285,840)	(1.92%)
Percent of All Costs	27.8%	29.4%	1.64%	--
Cost per Acre of All Biomass feedstock Produced	201.42	191.42	(10.00)	(4.97%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	36.58	(0.72)	(1.92%)
Cost per Gallon of Ethanol	0.4973	0.4878	(0.0095)	(1.91%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$35,069,947	(3,612,898)	(9.34%)
Percent of All Costs	72.2%	70.56%	(1.64%)	--
Cost per Acre of All Biomass feedstock Produced	522.25	458.74	(63.51)	(12.16%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	87.67	(9.04)	(9.34%)
Cost per Gallon of Ethanol	1.2894	1.1690	(0.1204)	(9.34%)

[a] In this scenario, HES land lease costs are reduced to -$42.50 per acre.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E143. Sensitivity Scenario 9A (HES Land Lease Costs are Reduced) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	228,419	sq ft	$105,073	28,292	0.19%
Office Space	7,645	sq ft	1,146,750	201,503	1.38%
Pole Barns	84,932	sq ft	1,189,048	208,935	1.43%
Inside Machinery Storage	25,455	sq ft	3,054,600	536,743	3.67%
Headquarters Land	236,064	sq ft	26,911	2,354	0.02%
Purchased Machinery					
Tractor Size 1	23	#	3,968,880	759,884	5.19%
Tractor Size 2	34	#	4,489,700	732,924	5.01%
Tractor Size 3	0		0.00	0.00	0.00%
Planter	7	#	461,188	264,065	1.80%
Harvester	13	#	4,804,974	1,184,676	8.10%
In-Field Buggy	46	#	1,679,000	265,812	1.82%
Transport Trucks	108	#	11,448,000	1,851,893	12.66%
High-Energy Sorghum Trailers	108	#	5,605,200	636,760	4.35%
Switchgrass Trailers	17	#	595,000	74,166	0.51%
Support Vehicles	28	#	980,000	233,891	1.60%
Storage Handling	34	#	4,182,850	563,295	3.85%
Disc	10	#	449,962	124,454	0.85%
Bedder	14	#	278,600	29,893	0.20%
Fertilizer Toolbar	8	#	120,000	21,373	0.15%
Cultivator	3	#	283,500	67,084	0.46%
Sprayer	2	#	453,256	79,564	0.54%
Hay Cutter	5	#	579,315	136,271	0.93%
Wheel Rake	3	#	64,875	19,249	0.13%
Square Baler	6	#	581,814	99,356	0.68%
Hipper	12	#	286,860	51,092	0.35%
Rolling Cultivator	4	#	121,160	34,293	0.23%
Land Plane	9	#	355,500	95,461	0.65%
Bale Wagon	12	#	1,745,184	371,483	2.54%
Hay Squeeze	10	#	1,365,250	281,010	1.92%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	11.37%
Re-Lift Pump	258	#	4,450,500	424,682	2.90%
SG Custom Establishment					
SG Harvest Production	37,796	acres	11,274,547	829,402	5.67%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.00%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.30%
Purchase Storage	149	#	15,883,400	1,459,352	9.97%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.59%
Total Cost			$116,677,139	$14,633,517	100.00%

Table E144. Sensitivity Scenario 9A (HES Land Lease Costs are Reduced) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$872,368	2.49%
Land				
HES Land	acres	38,653	(1,642,753)	-4.68%
SG Production Land	acres	37,796	850,410	2.42%
SG Insurance Land	acres	40,000	700,000	2.00%
Labor				
Hire Full-Time Labor	persons	160	7,828,400	22.32%
Hire Part-Time Labor	hours	41,275	556,856	1.59%
Irrigation				
Pump Groundwater	acre-inches	644,346	3,607,106	10.29%
HES Field Operations				
Disc	n/a	n/a	135,795	0.39%
Disc	n/a	n/a	135,795	0.39%
Land Plane	n/a	n/a	226,968	0.65%
Bed	n/a	n/a	71,849	0.20%
Hip Beds	n/a	n/a	74,363	0.21%
Fertilize	n/a	n/a	7,328,950	20.90%
Hip Beds	n/a	n/a	74,363	0.21%
Spray	n/a	n/a	462,902	1.32%
Condition Beds	n/a	n/a	76,802	0.22%
Always Planting	n/a	n/a	1,541,693	4.40%
Cultivate	n/a	n/a	86,013	0.25%
Always Harvesting	n/a	n/a	2,043,295	5.83%
Support Vehicles	n/a	n/a	26,105	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,437,249	9.80%
Transportation				
Transport HES	wet tons	958,709	2,273,161	6.48%
Transport SG	dry tons	100,000	353,171	1.01%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	8,986	90,136	0.26%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,888	67,787	0.19%
Overhead Management				
Overhead Management	persons	45	3,791,132	10.81%
Total cost			$35,069,947	100.00%

Table E145. Summary of Sensitivity Scenario 9A (HES Land Lease Costs are Reduced), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$14,633,517	$191.42	$36.58	$0.4878	29.44%
Annual Operating Costs	35,069,947	458.74	87.67	1.1690	70.56%
Total Cost	$49,703,464	$650.15	$124.26	$1.6568	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario, HES land rent costs are reduced to -$42.50 per acre.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E146. Critical Results for Sensitivity Scenario 9B (Irrigation Operating Costs are Reduced to Zero)[a], Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 9B Results[a]	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	38,653	1,808	4.91%
Acres of SG	37,225	37,797	572	1.54%
Total farm acres[d]	187,760	193,756	5,996	3.19%
HES Dry Ton Production	313,266	314,990	1,724	0.55%
HES Wet Ton Production	950,719	958,721	8,002	0.84%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.15	(0.35)	(4.13%)
Average SG Dry Ton Yield per Acre	2.69	2.65	(0.04)	(1.65%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	49,968,220	(3,633,983)	(6.78%)
Cost per Acre of All Biomass feedstock Produced	$723.67	$653.61	(70.06)	(9.68%)
Cost per Dry Ton of All Biomass feedstock Produced	$134.01	$124.92	(9.09)	(6.78%)
Cost per Gallon of Ethanol	$1.7867	$1.6656	(0.1211)	(6.78%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$116,677,380	(1,571,915)	(1.33%)
Annualized Investment Costs	$14,919,357	$14,633,535	(285,822)	(1.92%)
Percent of All Costs	27.8%	29.3%	1.49%	--
Cost per Acre of All Biomass feedstock Produced	$201.42	$191.41	(10.01)	(4.97%)
Cost per Dry Ton of All Biomass feedstock Produced	$37.30	$36.58	(0.72)	(1.92%)
Cost per Gallon of Ethanol	$0.4973	$0.4878	(0.0095)	(1.91%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$35,334,685	(3,348,160)	(8.66%)
Percent of All Costs	72.2%	70.71%	(1.49%)	--
Cost per Acre of All Biomass feedstock Produced	$522.25	$462.19	(60.06)	(11.50%)
Cost per Dry Ton of All Biomass feedstock Produced	$96.71	$88.34	(8.37)	(8.66%)
Cost per Gallon of Ethanol	$1.2894	$1.1778	(0.1116)	(8.65%)

[a] In this scenario, irrigation operating costs are reduced to zero.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E147. Sensitivity Scenario 9B (Irrigation Operating Costs are Reduced to Zero) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	228,419	sq ft	$105,073	$28,292	0.19%
Office Space	7,645	sq ft	1,146,750	201,503	1.38%
Pole Barns	84,932	sq ft	1,189,048	208,935	1.43%
Inside Machinery Storage	25,455	sq ft	3,054,600	536,743	3.67%
Headquarters Land	236,064	sq ft	26,911	2,354	0.02%
Purchased Machinery					
Tractor Size 1	23	#	3,968,880	759,884	5.19%
Tractor Size 2	34	#	4,489,700	732,924	5.01%
Tractor Size 3	0		0	0	0.00%
Planter	7	#	461,188	264,065	1.80%
Harvester	13	#	4,804,974	1,184,676	8.10%
In-Field Buggy	46	#	1,679,000	265,812	1.82%
Transport Trucks	108	#	11,448,000	1,851,893	12.66%
High-Energy Sorghum Trailers	108	#	5,605,200	636,760	4.35%
Switchgrass Trailers	17	#	595,000	74,166	0.51%
Support Vehicles	28	#	980,000	233,891	1.60%
Storage Handling	34	#	4,182,850	563,295	3.85%
Disc	10	#	449,962	124,454	0.85%
Bedder	14	#	278,600	29,893	0.20%
Fertilizer Toolbar	8	#	120,000	21,373	0.15%
Cultivator	3	#	283,500	67,084	0.46%
Sprayer	2	#	453,256	79,564	0.54%
Hay Cutter	5	#	579,315	136,271	0.93%
Wheel Rake	3	#	64,875	19,249	0.13%
Square Baler	6	#	581,814	99,356	0.68%
Hipper	12	#	286,860	51,092	0.35%
Rolling Cultivator	4	#	121,160	34,293	0.23%
Land Plane	9	#	355,500	95,461	0.65%
Bale Wagon	12	#	1,745,184	371,483	2.54%
Hay Squeeze	10	#	1,365,250	281,010	1.92%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	11.37%
Re-Lift Pump	258	#	4,450,500	424,682	2.90%
SG Custom Establishment					
SG Harvest Production	37,797	acres	11,274,787	829,420	5.67%
SG Insurance Production	40,000	acres	11,932,000	877,767	6.00%
Storage					
Storage Land	6,103,040	sq ft	1,220,608	190,068	1.30%
Purchase Storage	149	#	15,883,400	1,459,352	9.97%
Silo Cover	3,540,240	sq ft	885,060	233,022	1.59%
Total Cost			$116,677,380	$14,633,535	100.00%

Table E148. Sensitivity Scenario 9B (Irrigation Operating Costs are Reduced to Zero) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$878,956	2.49%
Land				
HES Land	acres	38,653	2,222,548	6.29%
SG Production Land	acres	37,797	850,433	2.41%
SG Insurance Land	acres	40,000	700,000	1.98%
Labor				
Hire Full-Time Labor	persons	160	7,828,400	22.16%
Hire Part-Time Labor	hours	41,275	556,855	1.58%
Irrigation				
Pump Groundwater	acre-inches	645,821	0	0.00%
HES Field Operations				
Disc	n/a	n/a	135,793	0.38%
Disc	n/a	n/a	135,793	0.38%
Land Plane	n/a	n/a	226,964	0.64%
Bed	n/a	n/a	71,848	0.20%
Hip Beds	n/a	n/a	74,362	0.21%
Fertilize	n/a	n/a	7,328,845	20.74%
Hip Beds	n/a	n/a	74,362	0.21%
Spray	n/a	n/a	462,895	1.31%
Condition Beds	n/a	n/a	76,801	0.22%
Always Planting	n/a	n/a	1,541,671	4.36%
Cultivate	n/a	n/a	86,012	0.24%
Always Harvesting	n/a	n/a	2,043,289	5.78%
Support Vehicles	n/a	n/a	26,105	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,437,308	9.73%
Transportation				
Transport HES	wet tons	958,721	2,273,183	6.43%
Transport SG	dry tons	100,000	353,171	1.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	8,986	90,140	0.26%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,889	67,789	0.19%
Overhead Management				
Overhead Management	persons	45	3,791,132	10.73%
Total cost			$35,334,685	100.00%

Table E149. Summary of Sensitivity Scenario 9B (Irrigation Operating Costs are Reduced to Zero), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$14,633,535	$191.41	$36.58	$0.4878	29.29%
Annual Operating Costs	35,334,685	462,19	88.34	1.1778	70.71%
Total Cost	$49,986,220	$653.61	$124.92	$1.6656	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario, irrigation operating costs are reduced to zero.
[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.
[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).
[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E150. Critical Results for Sensitivity Scenario 9C (No SG Harvest During April and May), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 9C[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	37,921	1,076	2.92%
Acres of SG	37,225	38,379	1,154	3.10%
Total farm acres[d]	187,760	192,142	4,382	2.33%
HES Dry Ton Production	313,266	317,796	4,530	1.45%
HES Wet Ton Production	950,719	965,050	14,331	1.51%
SG Dry Ton Production	100,000	100,000	0.00	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.38	(0.12)	(1.41%)
Average SG Dry Ton Yield per Acre	2.69	2.61	(0.08)	(3.14%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	54,331,838.12	729,635	1.36%
Cost per Acre of All Biomass feedstock Produced	723.67	712.08	(11.59)	(1.60%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	135.83	1.82	1.36%
Cost per Gallon of Ethanol	1.7867	1.8111	0.0244	1.36%
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$119,273,650	1,024,355	0.87%
Annualized Investment Costs	14,919,357	15,011,180	91,823	0.62%
Percent of All Costs	27.8%	27.6%	(0.17%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	196.74	(4.68)	(2.32%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	37.53	0.23	0.61%
Cost per Gallon of Ethanol	0.4973	0.5004	0.0031	0.62%
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$39,320,658	637,813	1.65%
Percent of All Costs	72.2%	72.4%	0.17%	--
Cost per Acre of All Biomass feedstock Produced	522.25	515.34	(6.91)	(1.32%)
Cost per Dry Ton of All Biomass feedstock Produced	96.71	98.30	1.59	1.65%
Cost per Gallon of Ethanol	1.2894	1.3107	0.0213	1.65%

[a] In this scenario, no SG is allowed to be harvested during April and May.
[b] Negative represents a reduction while a positive represents an increase in the variable.
[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.
[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E151. Sensitivity Scenario 9C (No SG Harvest During April and May) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	231,544	sq ft	$106,510	$28,679	0.19%
Office Space	7,630	sq ft	1,144,500	201,107	1.34%
Pole Barns	85,497	sq ft	1,196,958	210,325	1.40%
Inside Machinery Storage	26,460	sq ft	3,175,200	557,934	3.72%
Headquarters Land	239,174	sq ft	27,266	2,385	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,623,760	693,807	4.62%
Tractor Size 2	39	#	5,149,950	840,707	5.60%
Tractor Size 3	0		0	0	0.00%
Planter	7	#	461,188	264,065	1.76%
Harvester	13	#	4,804,974	1,184,676	7.89%
In-Field Buggy	49	#	1,788,500	283,148	1.89%
Transport Trucks	114	#	12,084,000	1,954,776	13.02%
High-Energy Sorghum Trailers	114	#	5,916,600	672,136	4.48%
Switchgrass Trailers	19	#	665,000	82,891	0.55%
Support Vehicles	27	#	945,000	225,538	1.50%
Storage Handling	35	#	4,305,875	579,863	3.86%
Disc	8	#	359,970	99,563	0.66%
Bedder	13	#	258,700	27,758	0.18%
Fertilizer Toolbar	8	#	120,000	21,373	0.14%
Cultivator	3	#	283,500	67,084	0.45%
Sprayer	2	#	453,256	79,564	0.53%
Hay Cutter	6	#	695,178	163,525	1.09%
Wheel Rake	4	#	86,500	25,665	0.17%
Square Baler	7	#	678,783	115,915	0.77%
Hipper	11	#	262,955	46,835	0.31%
Rolling Cultivator	4	#	121,160	34,293	0.23%
Land Plane	8	#	316,000	84,854	0.57%
Bale Wagon	14	#	2,036,048	433,397	2.89%
Hay Squeeze	11	#	1,501,775	309,111	2.06%
Irrigation					
Develop Irrigation Well Size 2	78	#	20,608,575	1,663,447	11.08%
Re-Lift Pump	253	#	4,364,250	416,452	2.77%
SG Custom Establishment					
SG Harvest Production	38,379	acres	11,448,456	842,196	5.61%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.85%
Storage					
Storage Land	6,225,920	sq ft	1,245,184	193,895	1.29%
Purchase Storage	152	#	16,203,200	1,488,735	9.92%
Silo Cover	3,611,520	sq ft	902,880	237,714	1.58%
Total Cost			$119,273,650	$15,011,180	100.00%

Table E152. Sensitivity Scenario 9C (No SG Harvest During April and May) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$978,150	2.49%
Land				
HES Land	acres	37,921	2,180,458	5.55%
SG Production Land	acres	38,379	863,528	2.20%
SG Insurance Land	acres	40,000	700,000	1.78%
Labor				
Hire Full-Time Labor	persons	170	8,317,675	21.15%
Hire Part-Time Labor	hours	40,331	544,123	1.38%
Irrigation				
Pump Groundwater	acre-inches	632,143	3,538,796	9.00%
HES Field Operations				
Disc	n/a	n/a	133,223	0.34%
Disc	n/a	n/a	133,223	0.34%
Land Plane	n/a	n/a	222,669	0.57%
Bed	n/a	n/a	70,488	0.18%
Hip Beds	n/a	n/a	72,955	0.19%
Fertilize	n/a	n/a	7,190,156	18.29%
Hip Beds	n/a	n/a	72,955	0.19%
Spray	n/a	n/a	454,136	1.15%
Condition Beds	n/a	n/a	75,347	0.19%
Always Planting	n/a	n/a	1,512,497	3.85%
Cultivate	n/a	n/a	84,384	0.21%
Always Harvesting	n/a	n/a	2,025,754	5.15%
Support Vehicles	n/a	n/a	25,611	0.07%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,479,941	8.85%
Transportation				
Transport HES	wet tons	965,050	2,288,987	5.82%
Transport SG	dry tons	100,000	353,171	0.90%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	5,654	56,713	0.14%
Transfer Tractor Hours 152 hp to 100 hp	hours	10,041	68,833	0.18%
Overhead Management				
Overhead Management	persons	46	3,876,855	9.86%
Total cost		.	$39,320,658	100.00%

Table E153. Summary of Sensitivity Scenario 9C (No SG Harvest During April and May), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Fuel[d]	% of Total Cost
Capital Investment Costs	$15,011,180	$196.74	$37.53	$0.5004	27.63%
Annual Operating Costs	39,320,658	515.34	98.30	1.3107	72.37%
Total Cost	$54,331,838	$712.08	$135.83	$1.8111	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario, no SG is allowed to be harvested during the April A, April B, May A, and May B periods.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per Dry Ton was determined using the total Dry Tons required by the conversion facility (400,000 Dry Tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E154. Critical Results for Sensitivity Scenario 9D (No Integer Programming), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 9D[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	36,845	36,691	(154)	(0.42%)
Acres of SG	37,225	37,375	150	0.40%
Total farm acres[d]	187,760	187,446	(314)	(0.17%)
HES Dry Ton Production	313,266	313,009	(257)	(0.08%)
HES Wet Ton Production	950,719	946,861	(3,858)	(0.41%)
SG Dry Ton Production	100,000	100,000	0	0.00%
Average HES Dry Ton Yield per Acre	8.50	8.53	0.03	0.37%
Average SG Dry Ton Yield per Acre	2.69	2.68	(0.01)	(0.54%)
Total Capital Investments and Operating Costs				
Annual Cost	$53,602,203	$53,490,626	($111,577)	(0.21%)
Cost per Acre of All Biomass feedstock Produced	723.67	722.21	(1.46)	(0.20%)
Cost per Dry Ton of All Biomass feedstock Produced	134.01	133.73	(0.28)	(0.21%)
Cost per Gallon of Ethanol	1.7867	1.7830	(0.0037)	(0.21%)
Capital Investment Costs				
Total Purchase Costs	$118,249,295	$116,690,229	($1,559,066)	(1.32%)
Annualized Investment Costs	14,919,357	14,767,608	(151,749)	(1.02%)
Percent of All Costs	27.8%	27.6%	(0.2%)	--
Cost per Acre of All Biomass feedstock Produced	201.42	199.39	(2.03)	(1.01%)
Cost per Dry Ton of All Biomass feedstock Produced	37.30	36.92	(0.38)	(1.02%)
Cost per Gallon of Ethanol	0.4973	0.4923	(0.0050)	(1.01%)
Annual Operating Costs				
Total Annual Operating Costs	$38,682,845	$38,723,018	$40,173	0.10%
Percent of All Costs	72.2%	72.4%	0.2%	--
Cost per Acre of All Biomass feedstock Produced	522.25	522.82	0.57	0.11%
Cost per Dry Ton of All Biomass feedstock Produced	96.71	96.81	0.10	0.10%
Cost per Gallon of Ethanol	1.2894	1.2908	0.0014	0.11%

[a] In this scenario, no integers are placed on headquarters, land, purchased machinery, full-time labor, irrigation wells, re-lift pumps, or storage.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E155. Sensitivity Scenario 9D (No Integer Programming) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	228,443	sq ft	$105,084	$28,295	0.19%
Office Space	7,407	sq ft	1,110,980	195,217	1.32%
Pole Barns	84,432	sq ft	1,182,047	207,705	1.41%
Inside Machinery Storage	26,086	sq ft	3,130,360	550,055	3.72%
Headquarters Land	235,850	sq ft	26,887	2,352	0.02%
Purchased Machinery					
Tractor Size 1	21	#	3,549,776	679,642	4.60%
Tractor Size 2	39	#	5,144,480	839,815	5.69%
Tractor Size 3	0	#	0.00	0.00	0.00%
Planter	6	#	422,977	242,186	1.64%
Harvester	13	#	4,974,608	1,226,499	8.31%
In-Field Buggy	49	#	1,798,960	284,804	1.93%
Transport Trucks	115	#	12,221,439	1,977,009	13.39%
High-Energy Sorghum Trailers	115	#	5,983,893	679,781	4.60%
Switchgrass Trailers	19	#	677,925	84,502	0.57%
Support Vehicles	26	#	902,583	215,415	1.46%
Storage Handling	35	#	4,292,626	578,078	3.91%
Disc	8	#	370,510	102,478	0.69%
Bedder	13	#	264,307	28,359	0.19%
Fertilizer Toolbar	7	#	111,663	19,888	0.13%
Cultivator	2	#	196,119	46,407	0.31%
Sprayer	1	#	299,719	52,613	0.36%
Hay Cutter	6	#	688,083	161,856	1.10%
Wheel Rake	3	#	69,797	20,709	0.14%
Square Baler	7	#	694,807	118,652	0.80%
Hipper	11	#	257,972	45,947	0.31%
Rolling Cultivator	3	#	99,285	28,101	0.19%
Land Plane	7	#	287,934	77,318	0.52%
Bale Wagon	14	#	2,084,982	443,814	3.01%
Hay Squeeze	12	#	1,600,874	329,509	2.23%
Irrigation					
Develop Irrigation Well Size 2	72	#	19,013,671	1,534,712	10.39%
Re-Lift Pump	245	#	4,219,414	402,631	2.73%
SG Custom Establishment					
SG Harvest Production	37,375	acres	11,148,901	820,159	5.55%
SG Insurance Production	40,000	acres	11,932,000	877,767	5.94%
Storage					
Storage Land	6,047,569	sq ft	1,209,514	188,341	1.28%
Purchase Storage	148	#	15,739,035	1,446,088	9.79%
Silo Cover	3,508,063	sq ft	877,016	230,904	1.56%
Total Cost			$116,690,229	$14,767,608	100.00%

Table E156. Sensitivity Scenario 9D (No Integer Programming) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$963,277	2.49%
Land				
HES Land	acres	36,691	2,109,707	5.45%
SG Production Land	acres	37,375	840,933	2.17%
SG Insurance Land	acres	40,000	700,000	1.81%
Labor				
Hire Full-Time Labor	persons	172	8,410,468	21.72%
Hire Part-Time Labor	hours	40,847	551,091	1.42%
Irrigation				
Pump Groundwater	acre-inches	611,632	3,423,971	8.84%
HES Field Operations				
Disc	n/a	n/a	128,900	0.33%
Disc	n/a	n/a	128,900	0.33%
Land Plane	n/a	n/a	215,444	0.56%
Bed	n/a	n/a	68,201	0.18%
Hip Beds	n/a	n/a	70,588	0.18%
Fertilize	n/a	n/a	6,956,853	17.97%
Hip Beds	n/a	n/a	70,588	0.18%
Spray	n/a	n/a	439,400	1.13%
Condition Beds	n/a	n/a	72,903	0.19%
Always Planting	n/a	n/a	1,463,420	3.78%
Cultivate	n/a	n/a	81,646	0.21%
Always Harvesting	n/a	n/a	1,971,356	5.09%
Support Vehicles	n/a	n/a	24,780	0.06%
SG Field Operations				
Grow and Harvest	n/a	n/a	3,406,404	8.80%
Transportation				
Transport HES	wet ton	946,861	2,247,925	5.81%
Transport SG	dry tons	100,000	353,171	0.91%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	6,272	62,919	0.16%
Transfer Tractor Hours 152 hp to 100 hp	hours	9,778	67,032	0.17%
Overhead Management				
Overhead Management	persons	46	3,893,112	10.05%
Total cost			$38,723,018.	100.00%

Table E157. Summary of Sensitivity Scenario 9D (No Integer Programming), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Ethanol[d]	% of Total Cost
Capital Investment Costs	$14,767,608	$199.39	$36.92	$0.4923	27.61%
Annual Operating Costs	38,723,018	522.82	96.81	1.2908	72.39%
Total Cost	$53,490,626	$722.21	$133.73	$1.7830	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario no integers are placed on headquarters, land, purchased machinery, full-time labor, irrigation wells, re-lift pumps, or storage.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons required by the conversion facility (400,000 dry tons).

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

Table E158. Critical Results for Sensitivity Scenario 9E (No Integer Programming on Economies of Size), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Item	Year 2 Baseline Results	Sensitivity Scenario 9D[a] Results	Change	% Change[b,c]
Production Level				
Acre of HES	2,496	2,474	(22)	(0.89%)
Acres of SG	0	0	0	0
Total farm acres[d]	7,488	47,421	39,993	84.21%
HES Dry Ton Production	22,990	22,967	(23)	(0.10%)
HES Wet Ton Production	68,660	68,663	3	0.00%
SG Dry Ton Production	0	0	0	0
Average HES Dry Ton Yield per Acre	9.21	9.28	0.07	0.75%
Average SG Dry Ton Yield per Acre	0.00	0.00	0	0
Total Capital Investments and Operating Costs				
Annual Cost	$5,622,749	$5,089,243	(533,506)	(10.48%)
Cost per Acre of All Biomass feedstock Produced	2,252.70	2,057.29	(195.41)	(9.50%)
Cost per Dry Ton of All Biomass feedstock Produced	261.52	236.71	(24.81)	(10.48%)
Cost per Gallon of Ethanol	3.4870	3.1561	(0.33)	(10.48%)
Capital Investment Costs				
Total Purchase Costs	$7,583,371	$6,867,034	(716,337)	(10.43%)
Annualized Investment Costs	1,072,424	931,970	(140,454)	(15.07%)
Percent of All Costs	19.1%	18.3%	(0.01)	(4.37%)
Cost per Acre of All Biomass feedstock Produced	429.66	376.74	(52.92)	(14.05%)
Cost per Dry Ton of All Biomass feedstock Produced	49.88	43.35	(6.53)	(15.06%)
Cost per Gallon of Ethanol	0.6651	0.5780	(0.09)	(15.07%)
Annual Operating Costs				
Total Annual Operating Costs	$4,550,325	4,157,272	(393,053)	(9.45%)
Percent of All Costs	80.9%	81.7%	0.01	0.98%
Cost per Acre of All Biomass feedstock Produced	1,823.05	1,680.55	(142.50)	(8.48%)
Cost per Dry Ton of All Biomass feedstock Produced	211.64	193.36	(18.28)	(8.45%)
Cost per Gallon of Ethanol	2.8219	2.5782	(0.24)	(9.45%)

[a] In this scenario, no integers are placed on headquarters, land, purchased machinery, full-time labor, irrigation wells, re-lift pumps, or storage.

[b] Negative represents a reduction while a positive represents an increase in the variable.

[c] Percentage change is measured by {[(Sensitivity Result - Baseline Result)/Baseline Result] x 100}.

[d] Includes HES non-planted rotation acreage and SG land grown for insurance.

Table E159. Sensitivity Scenario 9E (No Integer Programming on Economies of Size) Required Capital Investments, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity, 2010.

Capital Item	Amount Required	Unit Measure	Full Capital Investment Cost	Amortized Investment Cost	% of Total Annual Cost
Headquarters					
Road Base	15,461	sq ft	$7,112	$1,915	0.21%
Office Space	247	sq ft	37,106	6,520	0.70%
Pole Barns	5,948	sq ft	83,269	14,632	1.57%
Inside Machinery Storage	1,659	sq ft	199,112	34,987	3.75%
Headquarters Land	15,709	sq ft	1,791	157	0.02%
Purchased Machinery					
Tractor Size 1	1	#	228,850	43,816	4.70%
Tractor Size 2	4	#	522,595	85,311	9.15%
Tractor Size 3	0	#	0	0	0.00%
Planter	0	#	18,248	10,448	1.12%
Harvester	1	#	319,350	78,736	8.45%
In-Field Buggy	4	#	156,965	24,850	2.67%
Transport Trucks	11	#	1,151,932	186,343	19.99%
High-Energy Sorghum Trailers	11	#	564,012	64,073	6.87%
Switchgrass Trailers	0	#	0	0	0.00%
Support Vehicles	2	#	60,854	14,524	1.56%
Storage Handling	3	#	396,108	53,343	5.72%
Disc	0	#	22,020	6,091	0.65%
Bedder	0	#	7,793	836	0.09%
Fertilizer Toolbar	1	#	10,143	1,807	0.19%
Cultivator	0	#	16,040	3,796	0.41%
Sprayer	0	#	15,069	2,645	0.28%
Hay Cutter	0	#	0	0	0.00%
Wheel Rake	0	#	0	0	0.00%
Square Baler	0	#	0	0	0.00%
Hipper	1	#	15,539	2,768	0.30%
Rolling Cultivator	0	#	9,027	2,555	0.27%
Land Plane	0	#	19,413	5,213	0.56%
Bale Wagon	0	#	0	0	0.00%
Hay Squeeze	0	#	0	0	0.00%
Irrigation					
Develop Irrigation Well Size 2	4	#	1,052,873	84,984	9.12%
Re-Lift Pump	16	#	284,482	27,146	2.91%
SG Custom Establishment					
SG Harvest Production	0	acres	0	0	0.00%
SG Insurance Production	0	acres	0	0	0.00%
Storage					
Storage Land	565,665	sq ft	113,133	17,617	1.89%
Purchase Storage	14	#	1,472,166	135,261	14.51%
Silo Cover	328,130	sq ft	82,033	21,598	2.32%
Total Cost			$6,867,034	$931,970	100.00%

Table E160. Sensitivity Scenario 9E (No Integer Programming on Economies of Size) Annual Operating Costs, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

Segment	Units	Amount Required	Cost	% of Total Variable Cost
Banking				
Borrow Operating Money	$		$103,083	2.48%
Land				
HES Land	acres	2,474	142,241	3.42%
SG Production Land	acres	0	0	0.00%
SG Insurance Land	acres	0	0	0.00%
Labor				
Hire Full-Time Labor	persons		68,141	1.64%
Hire Part-Time Labor	hours	15,561	209,947	5.05%
Irrigation				
Pump Groundwater	acre-inches	41,238	230,852	5.55%
HES Field Operations				
Disc	n/a	n/a	8,691	0.21%
Disc	n/a	n/a	8,691	0.21%
Land Plane	n/a	n/a	14,526	0.35%
Bed	n/a	n/a	4,598	0.11%
Hip Beds	n/a	n/a	4,759	0.11%
Fertilize	n/a	n/a	469,046	11.28%
Hip Beds	n/a	n/a	4,759	0.11%
Spray	n/a	n/a	29,625	0.71%
Condition Beds	n/a	n/a	4,915	0.12%
Always Planting	n/a	n/a	98,667	2.37%
Cultivate	n/a	n/a	5,505	0.13%
Always Harvesting	n/a	n/a	137,078	3.30%
Support Vehicles	n/a	n/a	1,671	0.04%
SG Field Operations				
Grow and Harvest	n/a	n/a	0	0.00%
Transportation				
Transport HES	wet ton	68,663	177,214	4.26%
Transport SG	dry tons	0	0	0.00%
Transfer Tractor Hours				
Transfer Tractor Hours 225 hp to 152 hp	hours	174	1,749	0.04%
Transfer Tractor Hours 152 hp to 100 hp	hours	0	0	0.00%
Overhead Management				
Overhead Management	persons	29	2,431,511	58.49%
Total cost			$4,157,272	100.00%

Table E161. Summary of Sensitivity Scenario 9D (No Integer Programming on Economies of Size), Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity Supplying 30-Million Gallon Cellulosic Conversion Facility, 2010.

	Annual Cost[a]	Annual Costs per Acre[b]	Annual Costs per Dry Ton of Biomass feedstock[c]	Annual Costs per Gallon of Ethanol[d]	% of Total Cost
Capital Investment Costs	$931,970	$376.74	$43.35	$0.5780	18.3%
Annual Operating Costs	4,157,272	1,680.55	193.36	2.5782	81.7%
Total Cost	$5,089,243	$2,057.29	$236.71	$3.1561	100.00%

[a] The baseline scenario Year 2 includes the production of only HES and SG biomass feedstock, SG land for insurance, and both full- and part-time labor. In this scenario no integers are placed on headquarters, land, purchased machinery, full-time labor, irrigation wells, re-lift pumps, or storage.

[b] Biomass feedstock refers to harvested HES and SG. Cost per acre was determined by adding the acres of HES and SG harvested, not including SG acreage for grown insurance.

[c] Cost per dry ton was determined using the total dry tons produced on the 2500 acre farm divided into total annual costs.

[d] Cost per gallon was determined assuming a conversion rate of 75 gallons of fuel per dry ton of biomass feedstock (Avant 2009).

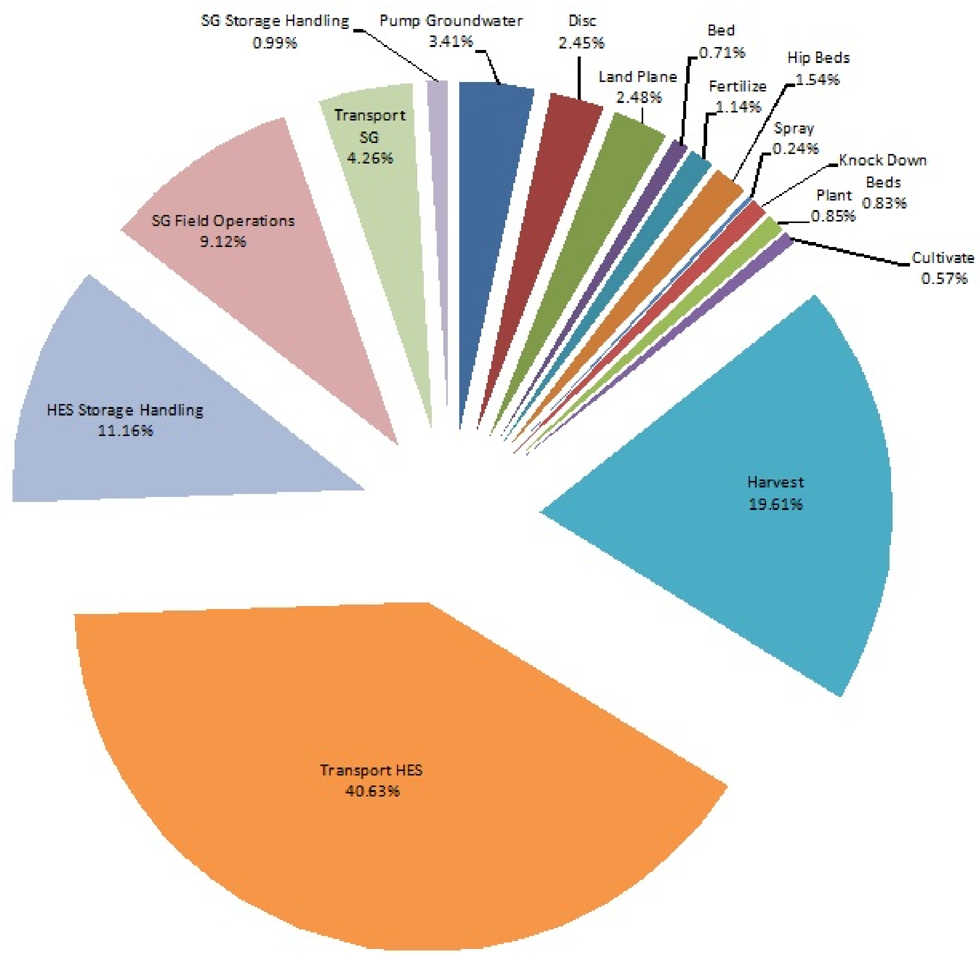

Figure E1. Year 2 Baseline Scenario Distribution of Labor Requirements, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity, 2010.

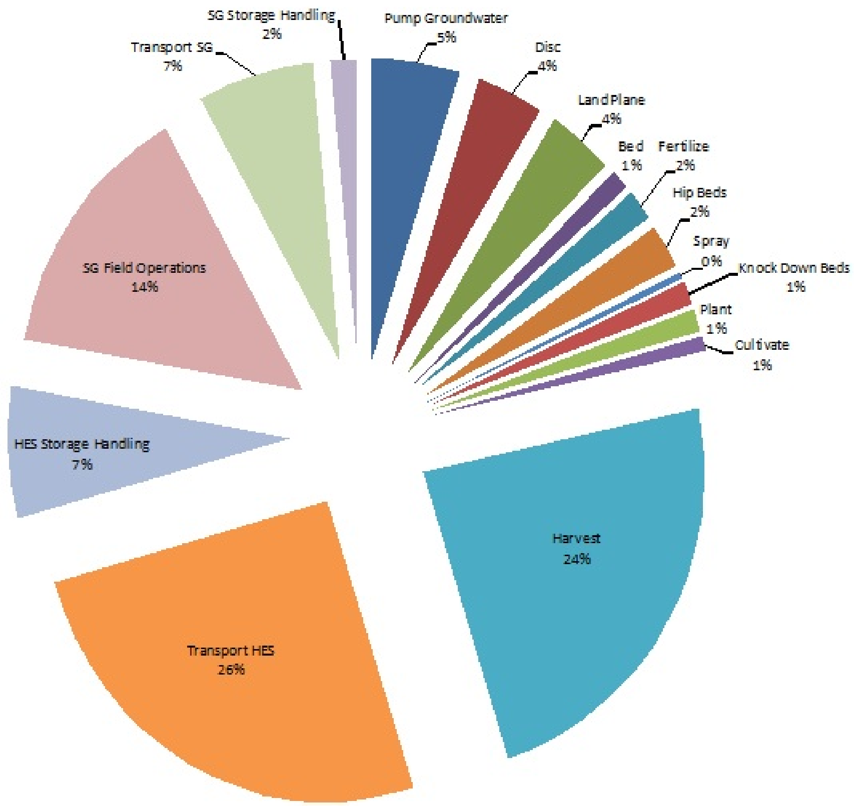

Figure E2. Sensitivity Scenario 6F Distribution of Labor Requirements, Hypothetical Middle Gulf Coast, Edna-Ganado, Texas Area Corporate Biomass Feedstock Farming Entity, 2010.

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